APPROACHES TO A TOTAL (OR GROUPED) VOC GUIDELINE

FINAL REPORT

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Environment

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Approaches to a Total (or Grouped) VOC Guideline

Final Report

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FOREWORD

Alberta Environment maintains Ambient Air Quality Guidelines to support air quality management in Alberta. Alberta Environment currently has ambient guidelines for thirty-one substances and five related parameters. These guidelines are periodically updated and new guidelines are developed as required. Fact Sheets on Ambient Air Quality Guidelines were updated in September 1997 and February 2000.

This document is prepared to support the development of a total (or grouped) volatile organic compound guideline.

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Project Manager
Science and Standards

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ABBREVIATIONS

AAQC	Ambient Air Quality Criteria
AENV	Alberta Environment
AIHA	American Industrial Hygiene Association
ARUG	Air Research Users Group
BAC	Best Available Controls
BACT	Best Available Control Technology
BEIS	Biogenic Emission Inventory System
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
CARB	California Air Resources Board
CCME	Canadian Council of Ministers of the Environment
CEC	Commission of the European Communities
CEPA	Canadian Environmental Protection Act
DHS	Department of Health Services (California)
EPA	Environmental Protection Agency (U.S.)
EPEA	Environmental Protection and Enhancement Act
ESL	Effects Screening Level
HVOC	High-Volatility Organic Compound
IDLH	Immediately Dangerous to Life and Health
LDAR	Leak Detection and Repair
LOAEL	Lowest Observed Adverse Effect Level
MDL	Method Detection Limit
MIR	Maximum Incremental Reactivity
MOE	Ministry of the Environment (Ontario)
MOR	Maximum Ozone Reactivity
MSG	Multi-Stakeholder Group
NAAQS	National Ambient Air Quality Standard
NAPS	National Air Pollution Surveillance
NH_3	Ammonium
NOAEL	No Observed Adverse Effect Level
NO_x	Nitrogen Oxide
NPRI	National Pollutant Release Inventory
O_3	Ozone
PAH	Polycyclic Aromatic Hydrocarbon
PAMZ	Parkland Airshed Management Zone
PIC	Product of Incomplete Combustion
PM	Particulate Matter
POI	Point of Impingement
PSL	Priority Substance List
RoC	Report on Carcinogens
RWC	Residential Wood Combustion
TC	Tolerable Concentration
TC_{05}	Tumorigenic Concentration
TD_{05}	Tumorigenic Dose

TDI	Tolerable Daily Intake
THC	Total Hydrocarbons
TNRCC	Texas Natural Resource Conservation Commission
US DHHS	United States Department of Health and Human Services
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WBEA	Wood Buffalo Environmental Association
WCAS	West Central Airshed Society
WHO	World Health Organization

SUMMARY

In October 2000, Alberta Environment held a priority-setting workshop with assistance from the Clean Air Strategic Alliance (CASA). At this workshop, members of the public, environmental organizations, government departments and industrial sectors identified a need for the development of an ambient volatile organic compound (VOC) guideline in Alberta. In response to the stakeholder input, in 2001 the Air and Water Branch of Alberta Environment included VOC guideline development in its three-year plan.

There are a number of approaches that may be considered during the process of developing a total VOC guideline. These approaches include assessment of the toxicology, odour potential, ozone formation capacity and particulate matter formation potential of VOC. This report presents the results of an investigation regarding these approaches as they could be applied in Alberta.

Available ambient VOC monitoring information from Alberta has been reviewed, and agencies and associations involved in monitoring have been identified. In Edmonton and Calgary, trend analyses have shown decreased ambient levels of alkanes, dienes and aromatic compounds since the commencement of operation of ambient monitoring stations. Concentrations of alkanes and alicyclic compounds are shown to be higher, on average, at the urban industrial site than at the urban residential sites, while alkynes and dienes are present at lower concentrations. While VOC emissions from biogenic sources account for 62% of total emissions in Alberta, anthropogenic sources such as the industrial and transportation sectors are also important contributors to ambient levels.

Air quality guidelines used in Alberta and other jurisdictions have been identified. While several Canadian, American and international jurisdictions currently have ambient guidelines in place for individual VOC species, none have developed a guideline for total VOC. However, total VOC has been addressed in some indoor guidelines, using a breakdown of hydrocarbon family concentrations within a VOC sample. These guidelines, while addressing different circumstances of exposure, may provide a useful background for developing an ambient total VOC guideline in Alberta.

1.0 INTRODUCTION

In October 2000, the Clean Air Strategic Alliance (CASA) facilitated a workshop aimed at identifying priorities with respect to ambient air quality guideline development in Alberta. Stakeholders present at the workshop included members of the public, representatives from environmental organizations, government departments and industrial sectors. From the results of workshop discussions, the need for an ambient volatile organic compound (VOC) guideline in Alberta was identified. In response to stakeholder input, in 2001 the Air and Water Branch included the development of a VOC guideline in its three-year plan.

Approaches to a Total (or Grouped) VOC Guideline is a project of Alberta Environment's Air Research Users Group (ARUG), aimed at identifying the various approaches that have been, and may be, used in the development of an ambient guideline for total VOC. This project began in June 2001, with the commencement of the scoping and information-gathering stages.

This report provides a summary of background information regarding: ambient concentrations and emissions of VOC in Alberta; endpoints and thresholds of VOC on human health and the environment; and VOC guidelines currently used in Alberta and around the world. This information is to be used in setting an air quality guideline for total VOC in Alberta. Alberta Environment uses ambient air quality guidelines as a tool for:

- Reporting on the state of the atmospheric environment in Alberta;
- Reporting to Albertans on the quality of air through an Air Quality index;
- Establishing approval conditions for regulated industrial facilities;
- Evaluating proposals to construct facilities that will have air emissions;
- Guiding special ambient air quality surveys; and,
- Assessing compliance near major industrial air emission sources.

The Canadian Council of Ministers of the Environment defines volatile organic compounds as compounds containing at least one carbon atom (excluding carbon dioxide and carbon monoxide) and with a vapour pressure of 0.01 kPa or greater at 25°C (CCME 1997). In general, methane is excluded from this definition, due to its lack of reactivity in the atmosphere. VOCs at elevated concentrations in ambient air are known to cause both carcinogenic and non-carcinogenic health effects in humans and animals. Many compounds react photochemically in the atmosphere to produce secondary pollutants such as ozone and particulate matter.

2.0 VOC EMISSIONS IN ALBERTA

Volatile organic compounds are emitted to ambient air from both anthropogenic and biogenic sources. They are emitted from anthropogenic sources primarily as a result of fuel production, distribution and combustion, as well as solvent evaporation. Vegetation is the primary source of biogenic VOC emissions; however, small amounts may also be released from ocean surfaces. Table 2-1 outlines the contributions of anthropogenic and biogenic sources toward ambient VOC concentrations in Alberta and Canada.

Table 2-1 Total anthropogenic and biogenic VOC emissions in Alberta and Canada in 1995 (Environment Canada 2001a and 2001b)

	Alberta (t)	Canada (t)
Total Anthropogenic Sources	762,732	3,575,202
Total Biogenic Sources	1,235,410	12,769,510
Total VOC Emissions	1,998,142	16,344,712

Biogenic emissions account for approximately 62% and 78% of total emissions in Alberta and Canada, respectively. VOC emissions in Alberta contribute toward 12% of total national emissions. The following sections provide a breakdown of emissions within Alberta.

2.1 Anthropogenic Emissions

There are a number of programs through which anthropogenic VOC emissions are monitored and estimated in Alberta. The National Pollutant Release Inventory (NPRI) is an important source of emission data for the province and Canada as a whole. Under the authority of the Canadian Environmental Protection Act (CEPA 1999), owners or operators of facilities that manufacture, process or otherwise use one or more of the NPRI-listed substances under prescribed conditions are required to report annually to the NPRI regarding the contaminants that they release into the environment.

Approximately 70 VOCs were reportable to the NPRI in 2000. According to the year 2000 inventory, the largest industrial contributors of VOC to the atmosphere were, in order of decreasing total emissions: crude petroleum and natural gas industries (5,704 t), chemical and chemical products industries (3,275 t), paper and allied products industries (989 t), wood industries (588 t) and food industries (584 t). Total reported VOC emissions in 2000 were 12,109 t; this represents a decrease of approximately 18% from emissions reported in 1995 (14,773 t). Table 2-2 presents a summary of the largest contributing industrial sources of VOC from facilities reporting to the NPRI in 1995 and 2000 in Alberta.

Table 2-2 Industrial sources of VOC in Alberta as reported to the National Pollutant Release Inventory in 1995 and 2000

Industry	1995 (t)	2000 (t)
Automobile Wrecking	2	
Chemical and Chemical Products Industries	8749	3275
Crude Petroleum and Natural Gas Industries	3643	5704
Fabricated Metal Products Industries (Except Machinery and Trans. Equipment Industries)	70	243
Food Industries		584
Non-metallic Mineral Products Industries	43	166
Other Manufacturing Industries		2
Paper and Allied Products Industries	1200	989
Pipeline Transport Industries	11	
Plastic Products Industries	153	263
Primary Metal Industries	35	48
Refined Petroleum and Coal Products Industries	482	241
Rubber Products Industries	11	
Service Industries Incidental to Mineral Extraction	6	7
Telecommunication Carriers Industry	6	
Transportation Equipment Industries	5	
Wood Industries	357	588
Total	**14773**	**12109**

There are a number of industrial sectors and facilities that are not required to report their emissions to the NPRI. In addition, many VOC emission sources (such as mobile and open sources) cannot be measured by practical means. As a result, the emissions reported in the NPRI do not represent total provincial emissions from anthropogenic sources.

Changes in VOC emissions reported to the NPRI for a particular industry may not reflect the actual change in emissions experienced, due to the contribution of smaller facilities that are not required to report to the NPRI. For example, while emissions from the crude petroleum and natural gas industries appear to have increased according to NPRI data, an overall decrease may have actually occurred due to a number of natural gas dehydrators that are not currently required to report their emissions. Data collected by the Technical Advisory Team on Benzene Emissions from Glycol Dehydrators suggests that emissions from these facilities decreased from 7240 t per year in 1995 to approximately 1600 t per year in 2001.

In 1995, Environment Canada estimated total anthropogenic emissions of VOC for each province on a sectoral basis (Environment Canada 2001*a*). The contribution of each sector toward total emissions in Alberta is displayed in Figure 2-1; a breakdown of anthropogenic emissions in Alberta and Canada on the whole can be found in Table A1-1 (Appendix 1).

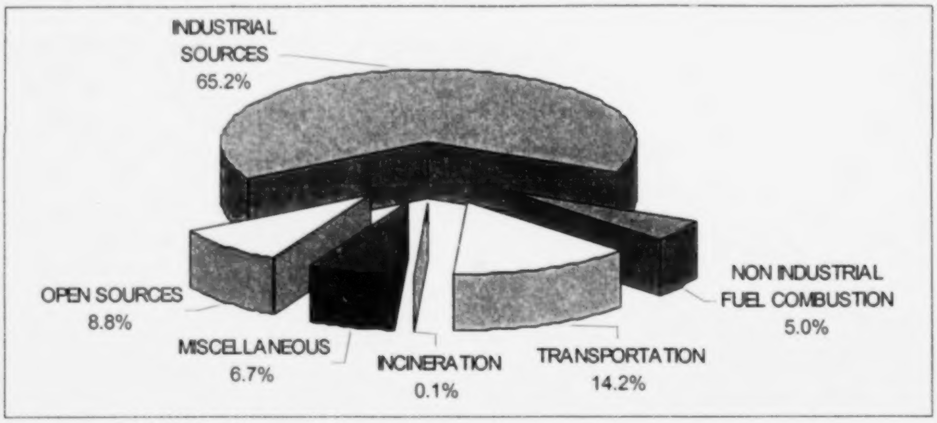


Figure 2-1 **Sectoral contributions toward VOC emissions in Alberta (adapted from Environment Canada 2001*a*)**

VOC emissions estimated by Environment Canada (2001*a*) differ significantly from those reported to the NPRI in 1995. This is due in large part to the exclusion of many small facilities from NPRI reporting requirements. Furthermore, estimates made by Environment Canada are based on total VOC, encompassing a large number of VOC species. The NPRI, on the other hand, requires facilities to report emissions for a much smaller suite of VOC.

Emissions estimates provided by Environment Canada (2001*a*) showed the five largest contributors of VOC emissions in Alberta to be: the upstream oil and gas industry (484,788 t), forest fires (61,356), light-duty gasoline vehicles (44,123 t), residential fuel wood combustion (36,033 t), light-duty gasoline trucks (28,982 t) and general solvent use (26,584 t). The Environment Canada estimates did not include emissions from vegetation. Emissions from sources in Alberta, as identified by Environment Canada (2001*a*), account for 21% of the national total (Figure 2-2).

A report by the Alberta Multi-Stakeholder Group (MSG) for Particulate Matter and Ozone also investigated anthropogenic VOC emissions in Alberta. Although the MSG report was based on data collected by Environment Canada, emissions were grouped according to individual airsheds defined by the MSG (Figure A1-1). Total anthropogenic VOC emissions from each airshed are displayed in Table A1-2.

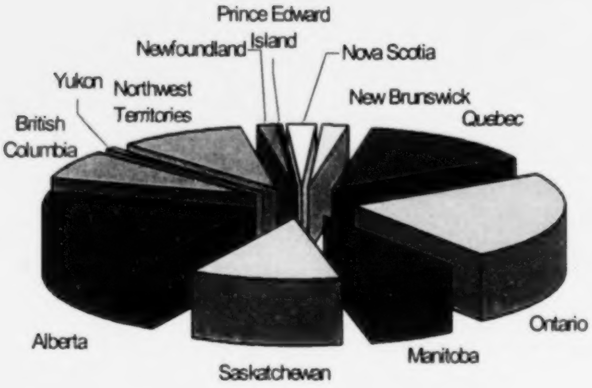


Figure 2-2 Relative anthropogenic VOC emissions in Canada in 1995 (adapted from Environment Canada 2001*a*)

The MSG report found anthropogenic VOC emissions to be greatest from the Calgary and Edmonton airshed regions (216,077 t and 146,619 t, respectively), followed by the Parkland and South Alberta airsheds (65,722 t and 62,009 t, respectively). Together, the Edmonton and Calgary airsheds account for nearly half of Alberta's total anthropogenic releases, ranking highest among the airsheds for miscellaneous sources (71% of total), non-industrial fuel combustion (51%), transportation (51%) and industrial sources (49%). Anthropogenic releases from open sources are most significant in the Northwest (36,034 t) and Athabasca/Cold Lake (25,612 t) airsheds; emissions from these airsheds account for 91% of total emissions from open sources in Alberta. The relative amount of VOC emitted from each sector in the airsheds is depicted in Figure 2-3.

2.2 Biogenic Emissions

While anthropogenic processes are an important source of VOCs to the atmosphere, biogenic (or natural) processes also play a prominent role in the release of these compounds. Natural sources of VOCs include releases from vegetation and ocean surfaces; of these, emissions from land vegetation typically have the greatest significance in terms of total emitted VOCs. Total VOC emissions from biogenic sources may exceed those from anthropogenic sources over a particular region. However, the nature of emitted VOCs may be quite different between the two source categories.

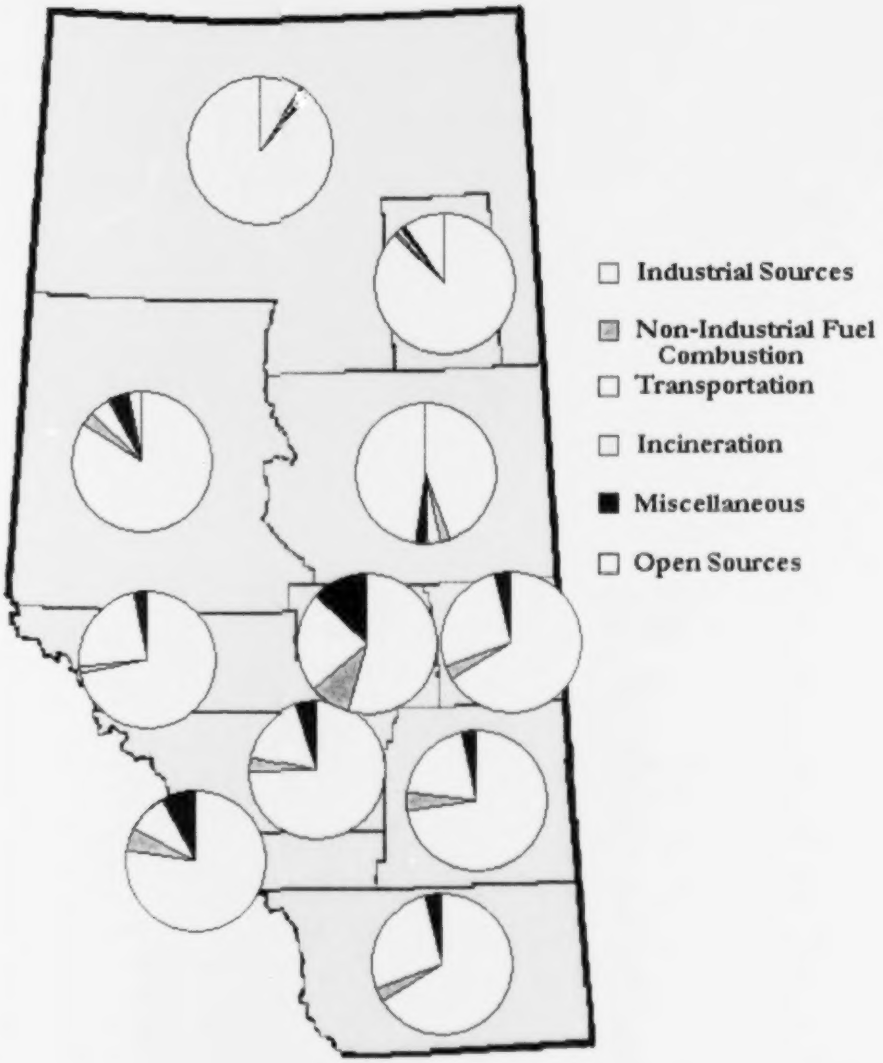

☐ Industrial Sources
▨ Non-Industrial Fuel Combustion
☐ Transportation
☐ Incineration
■ Miscellaneous
☐ Open Sources

Figure 2-3 VOC emissions from Alberta airsheds (based on results of MSG 1999)

Biogenic emissions of volatile organic compounds are very difficult to measure directly, due to the widespread distribution of vegetation. However, with the use of calculated emission factors, it is possible to estimate total emissions from a particular area or vegetation type. In 1995, Environment Canada estimated total biogenic VOC emissions for each Canadian province (Environment Canada 2001*b*; Table A2-1). Biogenic emissions of VOC were greatest in British Columbia, followed by Ontario, Québec and Alberta. Alberta's biogenic emissions were estimated at 1,235,410 t, exceeding estimated anthropogenic emissions (Environment Canada 2001*a*) by a factor of approximately 1.6. On a national level, biogenic emissions were estimated at 12,769,510, exceeding anthropogenic emissions by a factor of 3.6. Alberta's estimated biogenic emissions accounted for 9.7% of the national total (Figure 2-4).

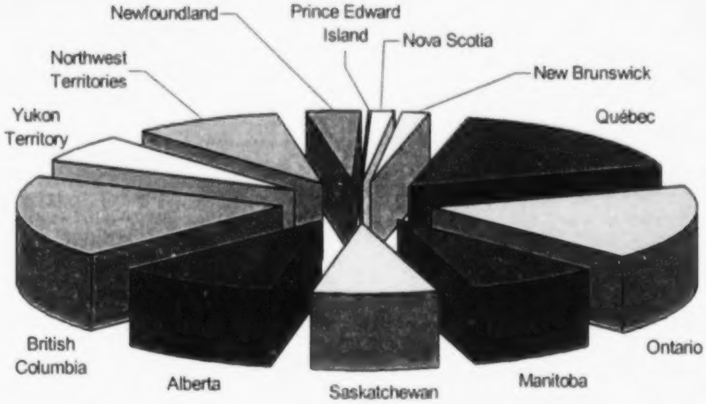


Figure 2-4 **Relative biogenic VOC emissions in Canada in 1995 (adapted from Environment Canada 2001b)**

A study by Man and Kharrat (2000) used models to estimate biogenic emission factors for various natural regions and vegetation types in Alberta (Table A2-2). Emission factors were estimated for isoprene and monoterpenes - the two major components of biogenic VOC emissions - and other, unidentified VOCs using the Biogenic Emission Inventory System (BEIS2) Model. From the calculated values, Man and Kharrat (2000) estimated emission factors for total VOCs. The results showed a connection between the amount of VOC emitted from biogenic sources and the dominant vegetation type in an area, as well as the ambient air temperature. Little difference was ascertained between VOC emissions from natural regions for a given vegetation type. Biogenic emission factors for deciduous, conifer and mixedwood vegetation were greater than those associated with pasture and urban areas.

3.0 AMBIENT VOC MONITORING IN ALBERTA

Ambient air quality monitoring is an essential component of Alberta's air quality management system. Monitoring of ambient volatile organic compounds in Alberta is carried out primarily by the provincial government and environmental associations. Table A3-1 presents details regarding the VOC monitoring stations in Alberta and the time periods over which the stations have been operational. The locations of these stations are presented in Figure 3-1. More detailed station maps are provided in Figures A3-1 through A3-4.

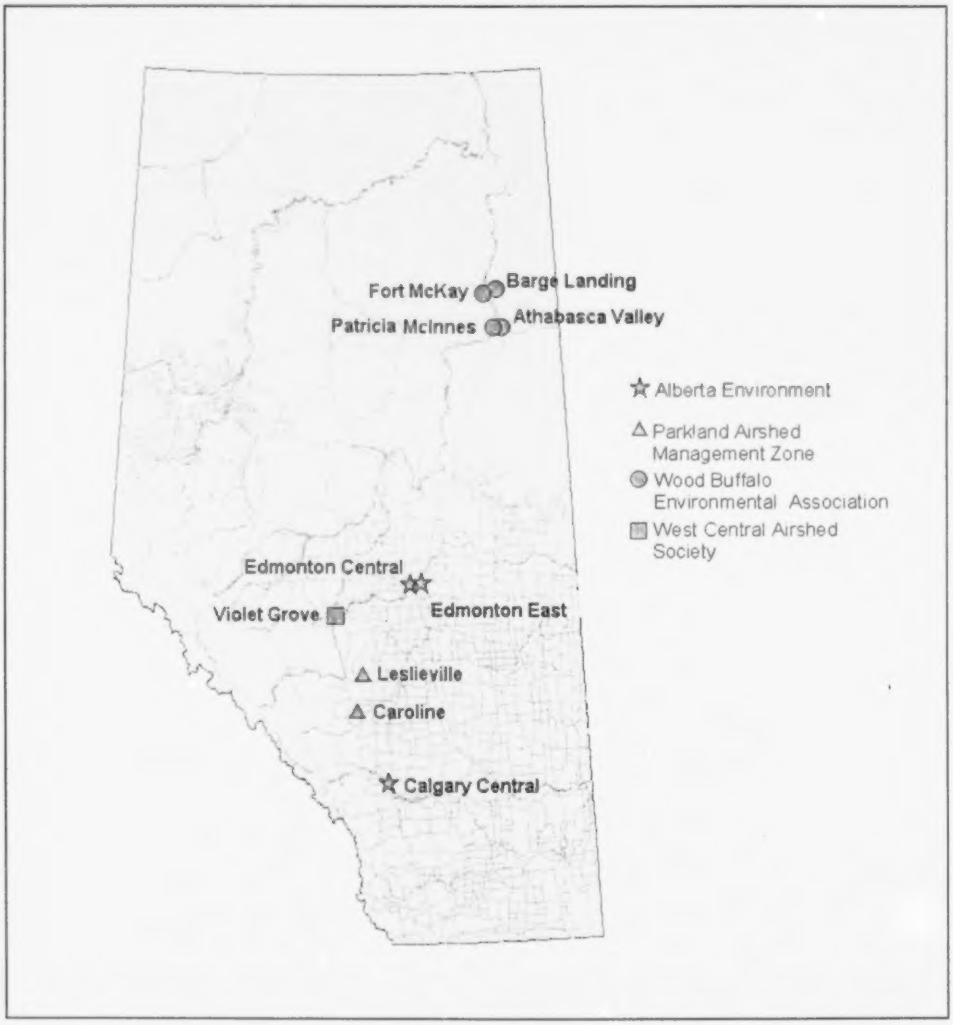

Fort McKay
Barge Landing
Patricia McInnes
Athabasca Valley
☆ Alberta Environment
△ Parkland Airshed Management Zone
● Wood Buffalo Environmental Association
▨ West Central Airshed Society
Edmonton Central
Violet Grove
Edmonton East
Leslieville
Caroline
Calgary Central

Figure 3-1 Locations of ambient VOC monitoring stations in Alberta

Alberta Environment has been monitoring ambient VOC concentrations in the province for the longest time of all organizations (approximately 12 years). AENV operates three VOC monitoring stations, with two in Edmonton (Edmonton Central and Edmonton East) and one in Calgary (Calgary Central). The Edmonton East station is located in an industrial area, while the Edmonton Central and Calgary Central stations are in urban environments.

Three environmental associations are involved in ambient VOC monitoring in Alberta: the Wood Buffalo Environmental Association (WBEA), the West Central Airshed Society (WCAS) and the Parkland Airshed Management Zone (PAMZ). The WBEA currently operates 11 air quality monitoring stations in the Regional Municipality of Wood Buffalo, of which four measure VOC concentrations. The WCAS has measured benzene, toluene, ethylbenzene and xylene (BTEX) concentrations at its Violet Grove station in the past, but is currently in the process of re-evaluating its monitoring program. Total hydrocarbon (THC) concentrations are being measured in the Parkland Airshed Management Zone at the Caroline and Leslieville stations. Several portable stations are also operated in the PAMZ on a rotational basis. The following sections examine data from each organization's ambient monitoring stations.

3.1 Alberta Environment

Alberta Environment has gathered a large body of data on ambient volatile organic compounds at its monitoring stations in Edmonton and Calgary. The Edmonton East and Calgary Central stations have been measuring VOCs since 1990, while the Edmonton Central station began monitoring in 1991. VOCs are monitored using a 6 L stainless steel electropolished (SUMMA) canister. Air samples are collected by drawing air into the canister at a constant rate (10 to 15 mL/min) for a 24-hour time period. These air samples are then analyzed by Gas Chromatography with Flame Ionization Detection (GC/FID) and Gas Chromatography Mass Spectrometer Detection (GC/MSD) systems using a cryogenic preconcentration technique to quantify concentrations of over 150 VOC species (Table A3-2). The SUMMA canisters are evacuated and cleaned prior to installation at the monitoring sites by the Environment Canada Environmental Technology Centre in Ottawa. Daily (24-hour) average concentrations are archived every six days, and analyses of the VOC samples are conducted by Environment Canada. A summary of individual VOC concentrations measured by AENV in 2000 is presented in Table A3-3.

Several AENV stations also measure total hydrocarbon (THC) concentrations in ambient air. THC is measured using continuous infrared (IR) analyzers. Concentrations are measured at 10-second intervals, and five-minute averages are recorded; one-hour averages are archived for analysis. AENV performs zero and three-point calibrations at its continuous monitoring stations monthly, and zero and span checks are done daily. Annual average THC concentrations at AENV stations are presented in Table 3-1.

AENV downloads THC concentration data into its provincial database daily and puts it through quality assurance steps before sending it to the National Air Pollution Surveillance (NAPS) Network quarterly. AENV performs audits on the sites every six months, while NAPS performs audits every two years. Independent audits are also done on the stations every two years.

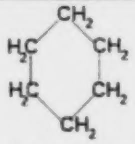
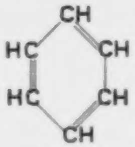
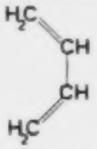
Table 3-1 Annual concentrations of total hydrocarbons (THC) measured at Alberta Environment monitoring stations

Station Name	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Calgary Central (ppm)	2.1947	2.1129	2.1625	2.2408	2.1203	2.1981	2.1847	2.1257	2.0895	2.0938
Calgary East (ppm)	2.0118	2.1869	2.2091	2.2432	2.236	2.2705	2.2218	2.2539	2.2312	2.1968
Calgary Northwest (ppm)	1.9435	2.0313	2.0721	1.9973	2.041	2.0023	2.085	2.1086	2.1175	2.0644
Edmonton Central (ppm)	2.5143	2.4625	2.344	2.111	2.2353	2.3259	2.4075	1.9588	1.9339	2.0888
Edmonton East (ppm)	2.4241	2.1904	2.2996	2.2227	2.4183	2.4822	2.2616	2.4241	2.5048	2.3695
Edmonton Northwest (ppm)	2.025	1.8824	2.1699	2.0221	2.0067	2.0549	2.2376	2.0868	2.2837	2.3145
Fort McMurray Athabasca Valley (ppm)	1.8849	2.0089	2.1576	1.9652	2.1807	1.9752	n/c	n/c	n/c	n/c
Fort Saskatchewan (100 Ave. And 98 St.) (ppm)	2.0801	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c
Fort Saskatchewan (9209a - 96 Ave.) (ppm)	n/c	1.8853	2.0373	1.9829	2.0946	1.9358	1.9512	1.9738	2.0267	1.9673
Red Deer (ppm)	n/c	n/c	n/c	n/c	n/c	n/c	n/c	2.3314	2.3069	2.2681
Sherwood Park (ppm)	n/c	n/c	n/c	n/c	n/c	2.1247	2.0849	2.068	2.0579	n/c

n/c – no data collected

It is useful to group the VOC monitoring results according to hydrocarbon family in order to compare constituents between monitoring sites. Six hydrocarbon families have been identified among the suite of VOC species monitored at AENV stations: alicyclics, alkanes, alkenes, alkynes, aromatics and dienes. A general description of each family can be found in Table 3-2.

Table 3-2 Descriptions of hydrocarbon families used in the analysis of Alberta Environment VOC monitoring data

Family	Synonyms	Structure	Example
Alicyclic	Cyclic	Ring, single and/or multiple C-C bonds (no conjugated double bonds)	 Cyclohexane
Alkane	Paraffin	Chain, single bonds between all C atoms	$H_3C-CH_2-CH_2-CH_3$ Butane
Alkene	Olefin	Chain, at least one C-C double bond	$H_2C=CH-CH_2-CH_3$ 1-Butene
Alkyne	Acetylene Hydrocarbon	Chain, at least one C-C triple bond	$HC\equiv C-CH_2-CH_3$ 1-Butyne
Aromatic		Ring, six C atoms with alternating single and double bonds	 Benzene
Diene	Diolefin	Chain, two C-C double bonds	 1,3-Butadiene

Mean annual concentrations are presented for each hydrocarbon family in Table 3-3. Mean annual alkane and alicyclic concentrations were considerably higher at the Edmonton East station than at the other two stations, while recorded alkyne and diene concentrations were lower. Increased alkane and alicyclic concentrations at the industrial site are likely due to local petroleum refining activity in the vicinity of the station. Data recorded at the Calgary Central station revealed a lower average concentration of aromatic compounds than found at the other two stations.

Annual concentrations were compared for each hydrocarbon family at AENV stations, over the period of time during which each station has been in operation. Comparisons revealed a decrease in ambient alkane, diene and aromatic concentrations at all three stations, along with increased alkene concentrations. The greatest percentage decreases of alkanes and dienes occurred at Edmonton East, while Edmonton Central recorded the greatest percentage decrease in aromatics and the greatest percentage increase in alkenes. All other concentration trends were negligible. Ambient VOC concentration trends are presented in Figure 3-2 (note that concentration scales are not comparable between hydrocarbon families).

3.2 Wood Buffalo Environmental Association

The Wood Buffalo Environmental Association (WBEA) is a collaboration of communities, industry and government located in the Regional Municipality of Wood Buffalo. In fulfillment of its objectives, the WBEA maintains a zonal air quality monitoring system in the Regional Municipality of Wood Buffalo. The WBEA operates four ambient air quality monitoring stations that measure speciated VOCs. Of these four stations, two are located in the vicinity of Fort McMurray (Athabasca Valley and Patricia McInnes), and two are located at or near Fort McKay (Fort McKay and Barge Landing) in northeastern Alberta.

The WBEA monitoring stations record ambient concentrations of approximately 50 individual VOC species. Passive samplers are used to measure average VOC concentrations over a specified time interval: every two weeks for the Athabasca Valley, Patricia McInnes and Fort McKay stations, and every week for the Barge Landing station. Chemical analysis of the monitoring data is performed by Maxxam Analytics Inc. In addition, the WBEA measures THC concentrations at several locations: Buffalo Viewpoint, Fort McKay, Athabasca Valley, Patricia McInnes, Lower Camp, Mannix and Mildred Lake. THC concentrations are measured using continuous sampling devices. The WBEA monitoring program consists of daily instrument calibration and monitoring of instrument performance with multi-point calibrations and regular government audits, according to the NAPS schedule. Air quality data is reviewed for systematic errors and archived for future reference.

Average annual VOC concentrations measured by WBEA monitoring stations can be found in Table A3-4. During 1999 and 2000, the most abundant VOCs in the Wood Buffalo Region were butane, isopentane, β-pinene, toluene and isobutane (in decreasing order), based on average concentrations between stations. Annual average THC concentrations are presented in Table 3-4.

3.3 West Central Airshed Society

The West Central Airshed Society (WCAS) is a non-profit society with representatives from agriculture, electrical utilities, gas transmission, oil and gas producers, forestry, municipal and provincial governments and environmental non-government organizations. The WCAS operates five air quality monitoring stations within the West Central Region of Alberta. Of these, only the Violet Grove station collects data regarding ambient VOC concentrations.

Table 3-3 **Mean annual VOC concentrations measured by AENV monitoring stations, grouped by hydrocarbon family**

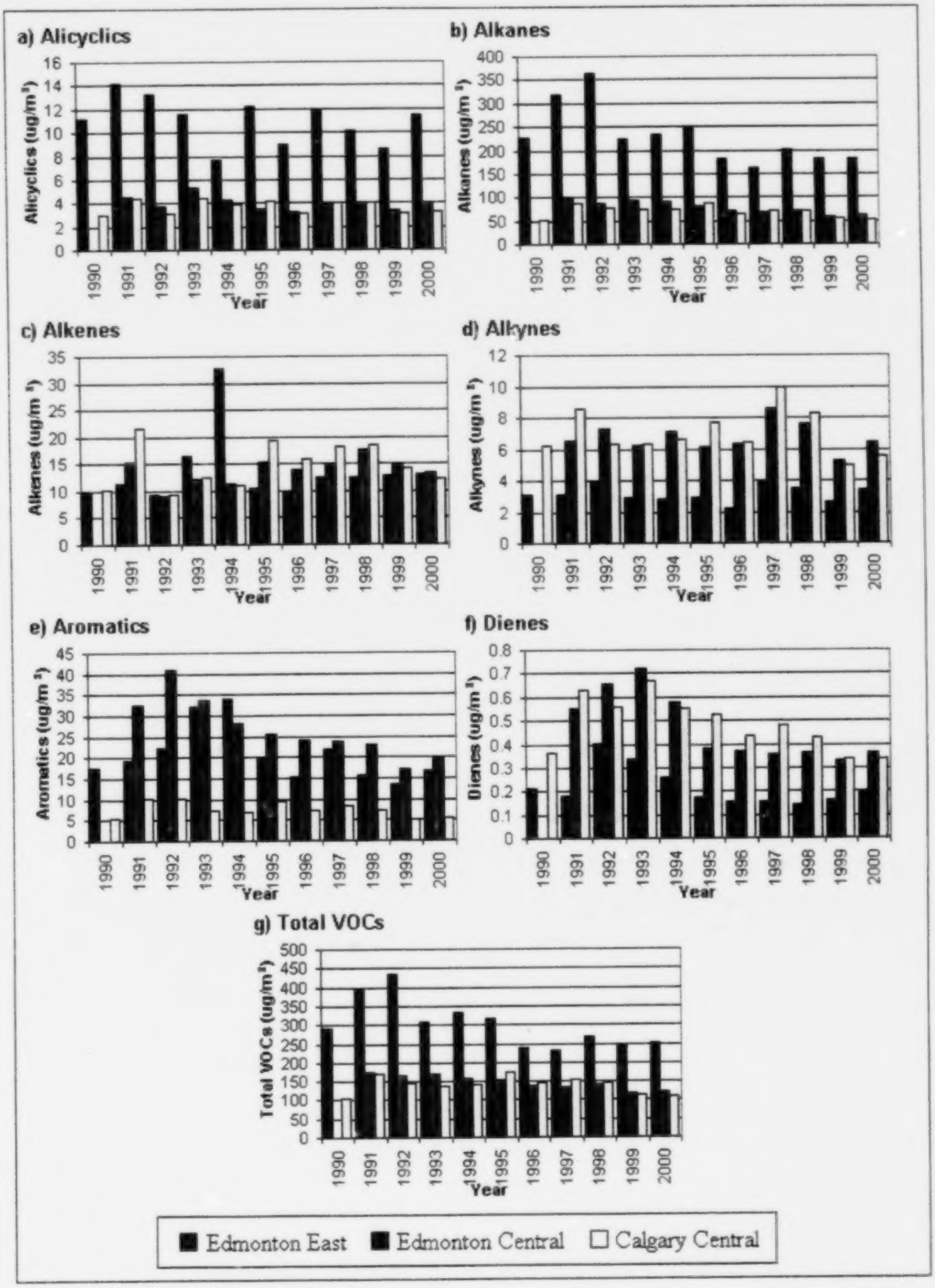
Hydrocarbon Family	Year	Edmonton East Annual Mean ($\mu g/m^3$)	Edmonton Central Annual Mean ($\mu g/m^3$)	Calgary Central Annual Mean ($\mu g/m^3$)
Alicyclics	1990*	11.21		2.96
	1991**	14.16	5.59	4.46
	1992	13.23	4.70	3.12
	1993	11.62	7.16	4.43
	1994	7.62	5.61	3.91
	1995	12.24	4.54	4.21
	1996	9.00	4.34	3.08
	1997	11.97	5.06	4.06
	1998	10.20	5.02	4.07
	1999	8.54	4.31	3.10
	2000	11.45	5.07	3.19
	Average	**11.02**	**5.14**	**3.69**
Alkanes	1990*	226.96		51.08
	1991**	319.14	96.29	86.40
	1992	365.45	89.18	76.97
	1993	224.20	93.81	76.06
	1994	234.32	91.08	76.40
	1995	246.40	81.81	86.45
	1996	181.12	71.70	66.57
	1997	162.15	66.76	72.61
	1998	201.65	72.34	70.85
	1999	182.35	60.06	53.81
	2000	183.17	62.28	50.80
	Average	**229.72**	**78.53**	**69.82**
Alkenes	1990*	9.79		10.38
	1991**	11.35	15.48	21.56
	1992	9.25	9.25	9.29
	1993	16.56	12.35	12.59
	1994	32.67	11.28	11.22
	1995	10.56	15.38	19.37
	1996	9.60	14.07	16.03
	1997	12.55	15.01	18.29
	1998	12.51	17.76	18.38
	1999	12.81	14.98	14.29
	2000	13.04	13.36	12.18
	Average	**13.70**	**13.89**	**14.87**

* From August 27, 1990 for Edmonton East; from August 9, 1990 for Calgary Central
** From May 18, 1991 for Edmonton Central

Table 3-3 (cont.) **Mean annual VOC concentrations measured by AENV monitoring stations, grouped by hydrocarbon family**

Hydrocarbon Family	Year	Edmonton East Annual Mean ($\mu g/m^3$)	Edmonton Central Annual Mean ($\mu g/m^3$)	Calgary Central Annual Mean ($\mu g/m^3$)
Alkynes	1990*	3.14		6.26
	1991**	3.08	6.50	8.61
	1992	3.88	7.29	6.37
	1993	2.91	6.28	6.33
	1994	2.79	7.13	6.59
	1995	2.89	6.11	7.75
	1996	2.28	6.34	6.46
	1997	4.01	8.55	9.99
	1998	3.56	7.58	8.27
	1999	2.64	5.25	4.94
	2000	3.44	6.42	5.59
	Average	**3.15**	**6.75**	**7.01**
Aromatics	1990*	17.49		5.59
	1991**	19.55	32.46	10.08
	1992	22.47	41.07	10.33
	1993	32.16	33.74	7.26
	1994	34.09	28.11	7.12
	1995	19.68	25.78	9.43
	1996	15.48	24.02	7.22
	1997	22.00	23.86	8.24
	1998	15.78	22.94	7.49
	1999	13.70	17.11	5.22
	2000	16.94	19.89	5.38
	Average	**20.85**	**26.90**	**7.58**
Dienes	1990*	0.21		0.36
	1991**	0.18	0.55	0.63
	1992	0.40	0.66	0.56
	1993	0.34	0.72	0.67
	1994	0.26	0.58	0.55
	1995	0.17	0.39	0.52
	1996	0.16	0.37	0.44
	1997	0.16	0.36	0.48
	1998	0.14	0.36	0.43
	1999	0.16	0.33	0.34
	2000	0.19	0.36	0.34
	Average	**0.22**	**0.47**	**0.48**

* From August 27, 1990 for Edmonton East; from August 9, 1990 for Calgary Central
** From May 18, 1991 for Edmonton Central



a) Alicyclics

b) Alkanes

c) Alkenes

d) Alkynes

e) Aromatics

f) Dienes

g) Total VOCs

Figure 3-2 Ambient concentrations of a) alicyclics, b) alkanes, c) alkenes, d) alkynes, e) aromatics and f) dienes at AENV monitoring stations

Table 3-4 Annual concentrations of total hydrocarbons (THC) measured at Wood Buffalo Environmental Association monitoring stations

Station Name	1997	1998	1999	2000
Buffalo Viewpoint (ppm)	n/c	n/c	2.1127	2.0616
Fort Mckay (ppm)	n/c	n/c	1.9656	1.9123
Fort McMurray Athabasca Valley (ppm)	2.1605	2.1233	1.9684	1.9967
Fort McMurray Patricia McInnes (ppm)	n/c	n/c	1.9508	1.9232
Lower Camp (ppm)	n/c	n/c	2.0568	2.024
Mannix (ppm)	n/c	n/c	1.9701	1.9484
Mildred Lake (ppm)	n/c	n/c	2.2702	2.2141

The Violet Grove station uses an integrated sampling system to collect VOC from the ambient atmosphere using reactive tubes, absorbents, and filters. The samples are chemically analyzed to provide an average concentration of the pollutant over a specified sampling interval. To date, ambient concentrations have been collected for BTEX compounds (benzene, toluene, ethyl benzene and xylenes) and total hydrocarbons (THC). Chemical analyses are performed by Maxxam Analytics Inc. Although this data has been collected since 1998, a low level of confidence in results prior to 2000 has been indicated by the society (Johnson, pers. comm.), resulting in a suspension of station operations.

In 2000, ambient concentrations of the BTEX compounds were collected on seven occasions (with two samples taken on each occasion). Measured concentrations of each compound are presented in Table A3-5. These results show toluene to be the most abundant BTEX compound, on average, measured at the Violet Grove station in 1999 and 2000. In 2000, the average total hydrocarbon concentration was 2.2691 ppm.

3.4 Parkland Airshed Management Zone

The Parkland Airshed Management Zone (PAMZ) Association is a multi-stakeholder, non-profit society established to identify air quality concerns within the zone and implement management solutions suited to those concerns. The PAMZ has as a key objective the establishment of a regional system to monitor air quality. The regional air quality monitoring system established by the PAMZ includes one continuous total hydrocarbon (THC) analyzer that has the ability to distinguish between methane (CH_4) and non-methane concentrations, and one portable continuous analyzer capable of monitoring THC only (the Caroline and Leslieville stations, respectively). In addition, four other portable continuous THC monitors have been used in the past, but are not currently operational; these are the Alix, Crossfield, Rimbey and Sundre stations.

Total hydrocarbon data are reported in methane equivalents, and chemical analyses are performed by RSLS Environmental Networks Inc. The PAMZ has tentative plans to use passive samplers to monitor VOC compounds in the future, but details of this plan have not yet been finalized. THC data from the PAMZ air monitoring stations are summarized in Table A3-6.

4.0 INDOOR EXPOSURE TO VOC

Although outdoor VOC concentrations are important indicators of human exposure in daily life, according to Health Canada people often spend more than 80% of their time indoors (Health Canada 2001). Therefore, human exposure to VOC may depend primarily on concentrations in indoor settings. Exposure in indoor settings can be a result of emissions from both outdoor and indoor sources; the relative contribution of each source depends on many factors, including the ventilation rate and age of the building, as well as the activities performed indoors.

Certain activities such as smoking tobacco products are major sources of many VOCs in indoor environments. For example, cigarette smoke may contain some polycyclic aromatic hydrocarbons (PAHs), phenols and aldehydes (Health Canada 2001). The United States Environmental Protection Agency (EPA) lists the following as the most common sources of VOC in the indoor environment: household products, including paints, paint strippers, and other solvents; wood preservatives; aerosol sprays; cleansers and disinfectants; moth repellents and air fresheners; stored fuels and automotive products; hobby supplies; and dry-cleaned clothing (EPA 2001). Building materials such as floor and wall coverings, insulation, fiberboard, plywood, solvents, adhesives and lacquers may also be important sources of VOCs in indoor environments. A complete listing of building materials that contribute to indoor VOC levels is presented in Table A4-1.

Ultimately, the quality of indoor air depends both on the quality of outdoor air and on the strength of emissions from indoor sources. According to Health Canada (2001), all contaminants in outdoor air are likely to be present indoors. Many pollutants, such as hydrocarbons, originate mostly from motor vehicle and factory emissions and other combustion processes. In the absence of indoor sources of these contaminants, their indoor concentrations will tend to be close to, or lower than, outdoor concentrations. Indoor concentrations of volatile organic compounds fluctuate greatly between different buildings. There are many factors that determine VOC levels present in any one indoor location. According to the EPA, concentrations of several VOCs average two to five times higher indoors than outdoors (EPA 2001*a*). Some activities, such as paint stripping, may increase indoor VOC levels to approximately 1,000 times those of background outdoor levels.

Certain VOCs may be emitted from new materials such as carpet and furniture, and may therefore be in greater abundance in newer buildings. For instance, the EPA has noted that average formaldehyde concentrations in older homes are generally well below 0.1 ppm, while homes with significant amounts of new pressed wood products may experience concentrations greater than 0.3 ppm (EPA 2001*b*). Formaldehyde is released from wood laminates and particleboard in which formaldehyde-containing resins have been used. According to Health Canada (2001), a common source of formaldehyde and other gaseous products in the recent past has been urea formaldehyde foam insulation (UFFI). The use of UFFI was banned by the Canadian government in 1980, due to concern about the health effects of inhaling vapours released from the insulation.

Combustion processes contribute greatly to the presence of VOCs in the indoor environment. For example, oven and pilot light emissions can contribute significantly to indoor levels of formaldehyde, due to the fact that they are not vented. Wood burning stoves and fireplaces are common emission sources of aldehydes, phenols and PAHs, as are kerosene space heaters.

Canadian surveys reported average formaldehyde concentrations in residences to be between 14 and 42 μg/m^3 (0.011 and 0.034 ppm) where urea-formaldehyde foam insulation was not used, and approximately 66 μg/m^3 (0.054 ppm) where it was used (Health Canada, 1987). This is in contrast to typical Canadian outdoor formaldehyde concentrations, reported by Health Canada, of approximately 10 μg/m^3 (0.008 ppm). The Health Canada report noted that indoor concentrations of acrolein typically range from 2 to 50 μg/m^3 (0.001 to 0.02 ppm), while levels of acetaldehyde average approximately 17 μg/m^3.

In 2000, Alberta Health and Wellness released a report that examined the exposure and health effects of air contaminants on residents of Fort McMurray (Alberta Health and Wellness 2000). Using personal air monitoring devices, researchers identified indoor and outdoor contaminant concentrations to which study participants were exposed. A model was then used to determine personal exposure. Benzene was among the contaminants monitored in the Alberta Health and Wellness report. Results of the study showed indoor concentrations to be the predominant factor affecting personal exposure to benzene; other factors were of relatively minor importance. Outdoor concentrations did not have a significant direct effect on personal exposure, but had a small indirect effect through indoor air. High benzene concentrations were recorded in some house garages and at gasoline service stations. Personal exposure of residents to benzene was 2.8 μg/m^3, a level slightly higher than that experienced by residents of the Lethbridge control group (2.1μg/m^3). Table 4-1 outlines median and 95th percentile benzene levels for Fort McMurray and Lethbridge. Ambient benzene levels in Fort McMurray were shown to be low and comparable to levels reported for rural areas in Canada. Personal exposure to benzene was greater than both indoor and outdoor exposure levels in both cities. In addition, indoor exposure was greater than outdoor exposure.

Table 4-1 Comparison of benzene levels between Fort McMurray and Lethbridge

Parameter	Units	Fort McMurray Median	Fort McMurray 95th	Lethbridge Median	Lethbridge 95th
Personal	μg/m^3	2.8	10.0	2.1	6.7
Indoor	μg/m^3	1.7	6.6	*	4.8
Outdoor	μg/m^3	1.3	5.5	*	3.6
Ambient	μg/m^3	1.2	3.1	N/A	N/A
P/I ratio		1.7	1.5	N/A	1.4
P/O ratio		2.05	1.82	N/A	1.90
I/O ratio		1.23	1.20	N/A	1.34
*Estimate not available due to small number of Lethbridge samples.					

5.0 VOC ENDPOINTS AND THRESHOLDS

Human and animal health may be negatively impacted through exposure to VOCs via direct pathways, such as inhalation or ingestion. Impacts may range from degradation of the respiratory, digestive and nervous systems to the development of tumours. Malodourous properties of certain VOCs may decrease the quality of life experienced by humans and animals. Products of interactions between VOCs and other components of the atmosphere may pose further threats to the environment. Certain VOCs undergo photochemical oxidation in the atmosphere, producing elevated concentrations of ground-level ozone which, in turn, impacts negatively on the health of human, animal and plant life. During the process of photochemical oxidation VOCs may also produce secondary VOCs, which may react to produce ozone themselves. Some VOCs may be transformed to particulate matter. In this form, these compounds may lead to respiratory difficulties in humans and animals and decrease the growth and productivity of vegetation.

5.1 Health Effects of VOC

5.1.1 Carcinogenic Effects

The ability of a substance to cause cancer in humans and animals is an important determinant of the negative effects of the substance on human health and the environment. Several VOCs have been shown, or are expected, to have carcinogenic effects at varying levels of exposure, based on scientific studies. According to the United States Environmental Protection Agency (EPA), VOCs typically account for 35 to 55% of outdoor air cancer risk in the United States (EPA 1990).

Because the carcinogenicity of VOCs varies between species, it is impossible to assess the potential carcinogenic health effects of total VOCs without knowing the absolute composition of a sample. Despite this, it is important to examine cancer risks associated with individual compounds in order to estimate the potential carcinogenicity of total VOCs.

The United States Department of Health and Human Services (DHHS) releases a Report on Carcinogens (RoC) on a biennial basis. The RoC contains the following information (DHHS 2001):

- a list of all substances which are known or may reasonably be anticipated to be human carcinogens, and to which a significant number of persons residing in the United States are exposed;
- information concerning the nature of exposure to these substances and the estimated number of persons exposed;
- a statement identifying the extent to which federal standards decrease the risk to public health from exposure to a substance; and
- a description of each request received during the year to conduct research into the carcinogenicity of substances and the associated response issued by the DHHS.

The two categories of carcinogen identified by the Department of Health and Human Services are: known to be a human carcinogen, in the case that there is sufficient evidence of carcinogenicity from human studies that indicates a causal relationship between exposure to the compound; and, reasonably anticipated to be a human carcinogen, in the case that there is limited evidence of carcinogenicity in humans and/or sufficient evidence of carcinogenicity in experimental animals.

Tables A5-1 and A5-2 present the organic compounds listed in the Ninth RoC (DHHS 2001) as known or anticipated human carcinogens. The Report does not present quantitative assessments of carcinogenic risk. Listing of substances in the Report, therefore, does not establish that these substances necessarily present carcinogenic risks to individuals in their daily lives.

The US EPA, in its 1990 report entitled *Cancer Risk from Outdoor Exposure to Air Toxics* (EPA 1990), provided a summary of nationwide annual cancer cases estimated to have been caused by certain pollutants (Table A5-3). Of the 27 pollutants indicated, 17 are VOCs; an additional three (coke oven emissions, gasoline vapours and products of incomplete combustion) are mixtures that may contain VOCs. According to the EPA report, the greatest number of pollutant-related cancer cases were caused by products of incomplete combustion (PICs), 1,3-butadiene and hexavalent chromium, in decreasing order of importance. Other important pollutant species included benzene, formaldehyde and chloroform. Of the estimated 1,726 to 2,706 cancer cases caused by air pollutants, individual VOCs account for approximately 927; this represents between 34 and 54% of all estimated air pollutant-related cancer cases. The total of all individual VOCs combined with the three aforementioned VOC-containing mixtures accounts for between 79 and 81% of cancer cases due to exposure to ambient air.

In order to understand the potential cancer risk faced by residents, the US EPA published unit risk factors associated with individual pollutants (EPA 1990). The cancer risk associated with a particular substance in air is typically presented as an estimate of the probability that an individual will develop cancer following continuous exposure to the substance at a concentration of 1 $\mu g/m^3$ over a lifetime. Table A5-4 presents the EPA list of carcinogen unit risk factors for over 70 substances.

A selection of toxic VOCs has been analyzed for associated cancer risks at each of the three AENV monitoring stations. A summary of cancer risks is presented in Table 5-1. At all sites, 1,3-butadiene, benzene and carbon tetrachloride contributed most significantly to cancer risk. Of the three stations, cancer risk due to 1,3-butadiene and tetrachloroethylene was least at the Edmonton East station, while risk due to 1,2-dichloroethane, styrene and trichloroethylene was greatest. An analysis of cancer risks in Edmonton and Calgary by Cheng *et al.* (1996) found similar results. However, unlike the present study, Cheng *et al* (1996) found risks due to carbon tetrachloride to be greater in Edmonton East than in Edmonton Central.

Table 5-1 **Summary of toxic VOC concentrations and lifetime cancer risk at Calgary Central, Edmonton Central and Edmonton East sampling stations for the period 1990-2000**

Compound	Date	Edmonton East			Edmonton Central			Calgary Central		
		Average $(\mu g/m^3)$	Unit Risk $(\mu g/m^3)^{-1}$	Risk	Average $(\mu g/m^3)$	Unit Risk $(\mu g/m^3)^{-1}$	Risk	Average $(\mu g/m^3)$	Unit Risk $(\mu g/m^3)^{-1}$	Risk
1,3-Butadiene	1990	0.16	2.80E-04	4.61E-05		2.80E-04		0.31	2.80E-04	8.78E-05
	1991	0.13	2.80E-04	3.76E-05	0.51	2.80E-04	1.42E-04	0.58	2.80E-04	1.62E-04
	1992	0.35	2.80E-04	9.84E-05	0.61	2.80E-04	1.71E-04	0.56	2.80E-04	1.56E-04
	1993	0.29	2.80E-04	7.99E-05	0.65	2.80E-04	1.83E-04	0.62	2.80E-04	1.74E-04
	1994	0.21	2.80E-04	5.84E-05	0.53	2.80E-04	1.48E-04	0.51	2.80E-04	1.43E-04
	1995	0.17	2.80E-04	4.82E-05	0.39	2.80E-04	1.08E-04	0.52	2.80E-04	1.47E-04
	1996	0.16	2.80E-04	4.35E-05	0.37	2.80E-04	1.04E-04	0.44	2.80E-04	1.22E-04
	1997	0.16	2.80E-04	4.39E-05	0.36	2.80E-04	1.01E-04	0.48	2.80E-04	1.34E-04
	1998	0.14	2.80E-04	3.99E-05	0.36	2.80E-04	1.01E-04	0.43	2.80E-04	1.21E-04
	1999	0.16	2.80E-04	4.48E-05	0.33	2.80E-04	9.34E-05	0.34	2.80E-04	9.52E-05
	2000	0.19	2.80E-04	5.42E-05	0.36	2.80E-04	1.02E-04	0.34	2.80E-04	9.56E-05
Benzene	1990	3.05	8.30E-06	2.53E-05		8.30E-06		3.12	8.30E-06	2.59E-05
	1991	3.15	8.30E-06	2.61E-05	3.85	8.30E-06	3.19E-05	4.54	8.30E-06	3.77E-05
	1992	3.38	8.30E-06	2.81E-05	4.02	8.30E-06	3.34E-05	3.89	8.30E-06	3.23E-05
	1993	2.92	8.30E-06	2.42E-05	3.64	8.30E-06	3.02E-05	3.37	8.30E-06	2.80E-05
	1994	2.60	8.30E-06	2.15E-05	3.54	8.30E-06	2.94E-05	3.19	8.30E-06	2.65E-05
	1995	2.55	8.30E-06	2.12E-05	2.74	8.30E-06	2.28E-05	3.36	8.30E-06	2.79E-05
	1996	1.84	8.30E-06	1.52E-05	2.58	8.30E-06	2.15E-05	2.75	8.30E-06	2.28E-05
	1997	2.10	8.30E-06	1.74E-05	2.32	8.30E-06	1.92E-05	2.92	8.30E-06	2.43E-05
	1998	2.14	8.30E-06	1.77E-05	2.47	8.30E-06	2.05E-05	2.64	8.30E-06	2.19E-05
	1999	1.60	8.30E-06	1.33E-05	1.68	8.30E-06	1.40E-05	1.68	8.30E-06	1.40E-05
	2000	2.03	8.30E-06	1.68E-05	1.83	8.30E-06	1.52E-05	1.75	8.30E-06	1.45E-05
Carbon tetrachloride	1990	0.92	1.50E-05	1.37E-05		1.50E-05		0.90	1.50E-05	1.34E-05
	1991	0.71	1.50E-05	1.07E-05	0.91	1.50E-05	1.37E-05	0.82	1.50E-05	1.24E-05
	1992	0.63	1.50E-05	9.48E-06	0.64	1.50E-05	9.62E-06	0.75	1.50E-05	1.13E-05
	1993	0.77	1.50E-05	1.15E-05	0.77	1.50E-05	1.16E-05	0.77	1.50E-05	1.16E-05
	1994	0.76	1.50E-05	1.14E-05	0.75	1.50E-05	1.13E-05	0.73	1.50E-05	1.10E-05
	1995	0.69	1.50E-05	1.03E-05	0.70	1.50E-05	1.05E-05	0.65	1.50E-05	9.76E-06
	1996	0.66	1.50E-05	9.97E-06	0.67	1.50E-05	1.00E-05	0.66	1.50E-05	9.92E-06
	1997	0.69	1.50E-05	1.04E-05	0.70	1.50E-05	1.05E-05	0.67	1.50E-05	1.01E-05
	1998	0.63	1.50E-05	9.46E-06	0.63	1.50E-05	9.41E-06	0.65	1.50E-05	9.77E-06
	1999	0.64	1.50E-05	9.53E-06	0.63	1.50E-05	9.38E-06	0.62	1.50E-05	9.30E-06
	2000	0.71	1.50E-05	1.06E-05	0.72	1.50E-05	1.08E-05	0.74	1.50E-05	1.11E-05

Table 5-1 (cont.) **Summary of toxic VOC concentrations and lifetime cancer risk at Calgary Central, Edmonton Central and Edmonton East sampling stations for the period 1990-2000**

Compound	Date	Edmonton East			Edmonton Central			Calgary Central		
		Average ($\mu g/m^3$)	Unit Risk $(\mu g/m^3)^{-1}$	Risk	Average ($\mu g/m^3$)	Unit Risk $(\mu g/m^3)^{-1}$	Risk	Average ($\mu g/m^3$)	Unit Risk $(\mu g/m^3)^{-1}$	Risk
Chloroform	1990	0.15	2.30E-05	3.37E-06		2.30E-05		0.18	2.30E-05	4.08E-06
	1991	0.13	2.30E-05	2.88E-06	0.11	2.30E-05	2.64E-06	0.15	2.30E-05	3.39E-06
	1992	0.09	2.30E-05	2.07E-06	0.10	2.30E-05	2.39E-06	0.12	2.30E-05	2.75E-06
	1993	0.13	2.30E-05	3.00E-06	0.16	2.30E-05	3.61E-06	0.16	2.30E-05	3.71E-06
	1994	0.11	2.30E-05	2.48E-06	0.12	2.30E-05	2.75E-06	0.13	2.30E-05	2.99E-06
	1995	0.07	2.30E-05	1.68E-06	0.09	2.30E-05	1.98E-06	0.12	2.30E-05	2.67E-06
	1996	0.08	2.30E-05	1.82E-06	0.10	2.30E-05	2.32E-06	0.11	2.30E-05	2.44E-06
	1997	0.09	2.30E-05	2.18E-06	0.11	2.30E-05	2.54E-06	0.12	2.30E-05	2.66E-06
	1998	0.09	2.30E-05	1.99E-06	0.11	2.30E-05	2.47E-06	0.12	2.30E-05	2.86E-06
	1999	0.11	2.30E-05	2.42E-06	0.12	2.30E-05	2.65E-06	0.14	2.30E-05	3.20E-06
	2000	0.11	2.30E-05	2.59E-06	0.14	2.30E-05	3.18E-06	0.13	2.30E-05	3.08E-06
1,2-Dichloroethane	1990	0.26	2.60E-05	6.72E-06		2.60E-05		0.07	2.60E-05	1.94E-06
	1991	0.31	2.60E-05	8.09E-06	0.27	2.60E-05	6.98E-06	0.10	2.60E-05	2.49E-06
	1992	0.07	2.60E-05	1.89E-06	0.07	2.60E-05	1.75E-06	0.08	2.60E-05	2.02E-06
	1993	0.11	2.60E-05	2.76E-06	0.10	2.60E-05	2.50E-06	0.08	2.60E-05	2.02E-06
	1994	0.15	2.60E-05	3.95E-06	0.09	2.60E-05	2.43E-06	0.06	2.60E-05	1.56E-06
	1995	0.11	2.60E-05	2.83E-06	0.08	2.60E-05	1.99E-06	0.05	2.60E-05	1.29E-06
	1996	0.09	2.60E-05	2.35E-06	0.09	2.60E-05	2.37E-06	0.06	2.60E-05	1.44E-06
	1997	0.11	2.60E-05	2.85E-06	0.10	2.60E-05	2.63E-06	0.06	2.60E-05	1.69E-06
	1998	0.25	2.60E-05	6.47E-06	0.16	2.60E-05	4.26E-06	0.06	2.60E-05	1.46E-06
	1999	0.13	2.60E-05	3.47E-06	0.13	2.60E-05	3.35E-06	0.08	2.60E-05	2.05E-06
	2000	0.17	2.60E-05	4.40E-06	0.13	2.60E-05	3.41E-06	0.09	2.60E-05	2.22E-06
Dichloromethane	1990	0.49	4.70E-07	2.32E-07		4.70E-07			4.70E-07	
	1991	0.58	4.70E-07	2.73E-07	0.63	4.70E-07	2.95E-07	0.61	4.70E-07	2.85E-07
	1992	1.77	4.70E-07	8.32E-07	1.29	4.70E-07	6.06E-07	1.40	4.70E-07	6.60E-07
	1993	0.76	4.70E-07	3.58E-07	1.41	4.70E-07	6.63E-07	0.59	4.70E-07	2.76E-07
	1994	1.40	4.70E-07	6.57E-07	1.20	4.70E-07	5.64E-07	0.70	4.70E-07	3.29E-07
	1995	0.91	4.70E-07	4.27E-07	0.79	4.70E-07	3.73E-07	0.74	4.70E-07	3.46E-07
	1996	0.38	4.70E-07	1.77E-07	0.58	4.70E-07	2.71E-07	0.75	4.70E-07	3.54E-07
	1997	0.52	4.70E-07	2.45E-07	0.57	4.70E-07	2.70E-07	0.99	4.70E-07	4.65E-07
	1998	0.47	4.70E-07	2.21E-07	0.53	4.70E-07	2.50E-07	0.77	4.70E-07	3.64E-07
	1999	0.48	4.70E-07	2.24E-07	0.55	4.70E-07	2.60E-07	0.67	4.70E-07	3.14E-07
	2000	0.67	4.70E-07	3.14E-07	0.52	4.70E-07	2.42E-07	0.77	4.70E-07	3.63E-07

Table 5-1 (cont.) **Summary of toxic VOC concentrations and lifetime cancer risk at Calgary Central, Edmonton Central and Edmonton East sampling stations for the period 1990-2000**

Compound	Date	Edmonton East			Edmonton Central			Calgary Central		
		Average ($\mu g/m^3$)	Unit Risk $(\mu g/m^3)^{-1}$	Risk	Average ($\mu g/m^3$)	Unit Risk $(\mu g/m^3)^{-1}$	Risk	Average ($\mu g/m^3$)	Unit Risk $(\mu g/m^3)^{-1}$	Risk
Tetrachloroethylene	1990	0.32	5.80E-07	1.85E-07		5.80E-07		1.41	5.80E-07	8.15E-07
	1991	0.20	5.80E-07	1.17E-07	0.50	5.80E-07	2.89E-07	1.02	5.80E-07	5.92E-07
	1992	0.16	5.80E-07	9.51E-08	0.48	5.80E-07	2.78E-07	0.62	5.80E-07	3.62E-07
	1993	0.20	5.80E-07	1.14E-07	0.76	5.80E-07	4.43E-07	0.91	5.80E-07	5.27E-07
	1994	0.66	5.80E-07	3.85E-07	0.60	5.80E-07	3.45E-07	0.81	5.80E-07	4.70E-07
	1995	0.17	5.80E-07	1.01E-07	0.45	5.80E-07	2.62E-07	0.98	5.80E-07	5.69E-07
	1996	0.17	5.80E-07	1.01E-07	0.31	5.80E-07	1.79E-07	0.87	5.80E-07	5.03E-07
	1997	0.31	5.80E-07	1.80E-07	0.59	5.80E-07	3.39E-07	0.83	5.80E-07	4.83E-07
	1998	0.24	5.80E-07	1.39E-07	0.43	5.80E-07	2.51E-07	1.01	5.80E-07	5.88E-07
	1999	0.29	5.80E-07	1.68E-07	0.46	5.80E-07	2.69E-07	0.84	5.80E-07	4.89E-07
	2000	0.36	5.80E-07	2.08E-07	0.51	5.80E-07	2.95E-07	0.76	5.80E-07	4.42E-07
Styrene	1990	0.93	5.70E-07	5.29E-07		5.70E-07		0.27	5.70E-07	1.52E-07
	1991	1.07	5.70E-07	6.12E-07	0.38	5.70E-07	2.15E-07	0.27	5.70E-07	1.56E-07
	1992	0.50	5.70E-07	2.85E-07	0.81	5.70E-07	4.63E-07	0.41	5.70E-07	2.31E-07
	1993	0.89	5.70E-07	5.05E-07	0.50	5.70E-07	2.82E-07	0.29	5.70E-07	1.67E-07
	1994	0.77	5.70E-07	4.36E-07	0.33	5.70E-07	1.87E-07	0.39	5.70E-07	2.23E-07
	1995	1.00	5.70E-07	5.69E-07	0.32	5.70E-07	1.82E-07	0.61	5.70E-07	3.46E-07
	1996	0.96	5.70E-07	5.47E-07	0.32	5.70E-07	1.85E-07	0.26	5.70E-07	1.45E-07
	1997	1.79	5.70E-07	1.02E-06	0.58	5.70E-07	3.33E-07	0.35	5.70E-07	1.98E-07
	1998	0.57	5.70E-07	3.27E-07	0.25	5.70E-07	1.45E-07	0.21	5.70E-07	1.17E-07
	1999	0.91	5.70E-07	5.19E-07	0.31	5.70E-07	1.74E-07	0.27	5.70E-07	1.55E-07
	2000	0.92	5.70E-07	5.27E-07	0.25	5.70E-07	1.44E-07	0.27	5.70E-07	1.55E-07
Trichloroethylene	1990	0.15	1.70E-06	2.53E-07		1.70E-06		0.45	1.70E-06	7.72E-07
	1991	0.17	1.70E-06	2.82E-07	0.22	1.70E-06	3.72E-07	0.18	1.70E-06	2.99E-07
	1992	0.11	1.70E-06	1.88E-07	0.16	1.70E-06	2.66E-07	0.11	1.70E-06	1.88E-07
	1993	0.11	1.70E-06	1.95E-07	0.12	1.70E-06	2.02E-07	0.09	1.70E-06	1.48E-07
	1994	0.32	1.70E-06	5.42E-07	0.09	1.70E-06	1.61E-07	0.08	1.70E-06	1.33E-07
	1995	0.05	1.70E-06	9.22E-08	0.05	1.70E-06	7.72E-08	0.06	1.70E-06	1.09E-07
	1996	0.31	1.70E-06	5.31E-07	0.08	1.70E-06	1.31E-07	0.09	1.70E-06	1.55E-07
	1997	0.71	1.70E-06	1.21E-06	0.12	1.70E-06	1.96E-07	0.13	1.70E-06	2.24E-07
	1998	0.43	1.70E-06	7.36E-07	0.12	1.70E-06	2.02E-07	0.21	1.70E-06	3.56E-07
	1999	0.49	1.70E-06	8.39E-07	0.10	1.70E-06	1.78E-07	0.14	1.70E-06	2.35E-07
	2000	0.31	1.70E-06	5.35E-07	0.13	1.70E-06	2.23E-07	0.16	1.70E-06	2.66E-07

Health Canada (1996) has developed Tumorigenic Doses (TD_{05}s) and Concentrations (TC_{05}s) for a number of substances with anticipated carcinogenic health endpoints. These factors were established for those substances defined by CEPA as Group I ("carcinogenic to humans") and Group II ("probably carcinogenic to humans") carcinogens. These levels are not meant to express risk in absolute terms, but as a concentration or dose which causes a 5% increase in the incidence of, or deaths due to, tumours. It is assumed that there is no safe level to which a person may be exposed to carcinogenic substances; therefore TD_{05}s and TC_{05}s identify levels at which risk is sufficiently small so as to be essentially negligible compared with other societal risks (Health Canada 1996). Health Canada's Tumorigenic Doses and Concentrations are presented in Table A5-5.

5.1.2 Non-Carcinogenic Effects

A number of VOCs have been identified as having toxic human health endpoints. These endpoints vary widely between compounds and exposure pathways, but tend to affect the respiratory, digestive and central nervous systems. Toxicity levels have been used by a number of regulatory agencies in setting ambient concentration standards and guidelines for individual VOCs.

Health Canada (1996) has proposed a number of Tolerable Daily Intakes, Tolerable Concentrations, Tumorigenic Doses and Tumorigenic Concentrations for substances on CEPA's first priority substance list (PSL 1; CEPA 1999). Tolerable Concentrations (TC) provide a health-based goal for inhalation against which ambient concentrations of non-carcinogenic substances may be compared. Tumorigenic Concentrations (TC_{05}) perform a similar function, with respect to potentially carcinogenic substances. Tolerable Daily Intakes (TDI) provide a health-based goal for ingestion of non-carcinogenic substances, while Tumorigenic Doses (TD_{05}) provide a reference for ingestion of carcinogenic substances.

The values derived by Health Canada take into account toxicological and epidemiological data for inhalation and ingestion only, and are based solely on human health effects (Health Canada 1996). The intrinsic assumption is that exposure to a particular substance occurs over a lifetime. TDIs and TCs were developed for those substances which are considered to have threshold values, and represent the levels to which a person may be exposed over a lifetime without deleterious effects. TC_{05}s and TD_{05}s were established for carcinogenic substances (i.e. substances for which there is no threshold), and are discussed in the previous section. Health Canada's Tolerable Daily Intakes and Concentrations are listed in Table A5-5.

Health effects of total volatile organic compounds have been addressed by Health Canada in its examination of indoor air quality in office buildings (Health Canada 1995*a*). Estimates made by Health Canada, with regard to total VOC thresholds, are based on chronic exposure during the regular work week (approximately 40 hours per week). Although these threshold concentrations do not apply to exposure in the outdoor environment, they act as a reasonable reference for comparison. Table 5-2 presents a summary of Health Canada's (1995*a*) findings.

Table 5-2 Total VOC thresholds in office buildings, as they apply to human health (adapted from Health Canada 1995*a*)

Concentration (mg/m^3)	*Health Effect*
<0.3	Fatigue, headaches, drowsiness, dizziness, weakness, joint pains, peripheral numbness, euphoria, tightness in chest, unsteadiness, blurred vision, skin and eye irritation.
0.3-25	Complaint of strong odour, irritation and / or discomfort
>25	Temporary discomfort and respiratory irritation
NB: Hypersensitive individuals can have severe reactions to a variety of VOCs at very low concentrations	

The toxicity of certain atmospheric VOCs in indoor environments was explored by the California Department of Health Services (DHS) in its document entitled *Reducing Occupant Exposure to Volatile Organic Compounds (VOCs) from Office Building Construction materials: Non-binding Guidelines* (DHS 1996). The department examined primarily health effects in their development of indoor air quality guidelines. The six VOCs selected for guideline development were chosen because they are common indoor air contaminants, are listed by the California Air Research Board (CARB) as toxic, and have significant adverse health effects as determined by the DHS (1996). Table A5-6 outlines the human health effects associated with each of the selected VOCs as determined by the DHS, based on the assumption of approximately 40 hours of exposure per work week.

5.1.3 Odour and Annoyance

The malodourous properties of certain volatile organic compounds may lead to irritation or annoyance in humans. The term *odour threshold* is used to describe the theoretical minimum concentration of odourant necessary to be detected in a specified percentage (usually 50%) of the population (AIHA 1989). While odour threshold concentrations for many VOCs may be below those considered toxic to humans, their odours may decrease the general quality of life experienced by the population.

A number of researchers have attempted to identify odour detection and recognition thresholds that apply to the general population. The results of these studies are highly variable and depend on the study techniques used, the purity of compounds used and the sensitivity and ability of the volunteer subjects (CIVO and RID 1977, ASTM 1978). It has been estimated that sensitivity to odourants can vary by a factor of 100 to 1000 (CIVO and RID 1977). According to the American Industrial Hygiene Association (AIHA 1989), it is not uncommon for reported odour threshold values to range over four orders of magnitude for the same chemical.

In 1989, the AIHA published its report entitled *Odor Thresholds for Chemicals with Established Occupational Health Standards*. The goal of this report was to critique previously published reports on odour thresholds, and provide a basis for developing a best estimate of odour threshold concentrations. The AIHA determined best estimates as the geometric mean of acceptable odour threshold values found in previous studies. AIHA odour thresholds are presented in Table A5-7. Mean air odour thresholds listed in the AIHA (1989) report vary widely between substances, due to their respective intrinsic chemical properties. A minimum odour detection threshold is noted for ethyl acrylate, at a concentration of 0.00024 ppm; the maximum odour detection threshold is noted for methyl formate, at a concentration of 2000 ppm.

Odour thresholds are sometimes used as the basis for developing ambient air guidelines for individual compounds. For example, the World Health Organization, in its Air Quality Guidelines for Europe (WHO 2000), has developed a number of ambient air guidelines for substances with malodorous properties (Table 5-3). The WHO guidelines target substances with malodorous properties at concentrations below those where toxic effects occur, and aim to protect the public from odour nuisance. The guidelines are based on data provided by expert panels and field studies, regarding odour threshold concentrations.

Table 5-3 WHO ambient air guidelines for VOCs, based on sensory effects or annoyance reactions, using an averaging time of 30 minutes

Substance	Detection Threshold	Recognition Threshold	Guideline Value (30 min. average)
Carbon disulphide	200 $\mu g/m^3$	–	20 $\mu g/m^3$
Formaldehyde	0.03–0.6 mg/m^3	–	0.1 mg/m^3
Styrene	70 $\mu g/m^3$	210–280 $\mu g/m^3$	70 $\mu g/m^3$
Tetrachloroethylene	8 mg/m^3	24–32 mg/m^3	8 mg/m^3
Toluene	1 mg/m^3	10 mg/m^3	1 mg/m^3

The odour detection and recognition thresholds noted by the WHO are different from those identified by the AIHA (1989), reflecting different experimental procedures in determining the concentrations. However, the values provided in the WHO document are within the range of concentrations identified by the AIHA.

5.2 Environmental Effects of VOC

5.2.1 Ozone Formation Capacity

An important pathway that may ultimately lead to negative impacts on human health and the environment is the formation of ground-level ozone (O_3) through photochemical oxidation of certain VOCs. Ground-level ozone has been linked to negative impacts on human health, including lung damage, chest pains, coughing, nausea, throat irritation, and congestion; significant increases in symptoms have been observed following exposure to ozone as low as 60 ppb over a period of 16 to 28 minutes of heavy exercise (Health Canada 1999). Ground-level ozone has linked with negative vegetative effects, such as the reduced ability of plants to produce and store food, making them more susceptible to disease, insects, other pollutants and harsh weather. Ozone is the primary component of smog, the brownish haze that is commonly seen over urban areas during the summer (EPA 1997).

In the absence of atmospheric VOCs, ground-level ozone is formed and destroyed in a series of reactions involving nitrogen oxides (NO_x; a combination of NO and NO_2) (CCME 1997). However, in the presence of VOCs, this reaction is altered significantly. In this situation, VOCs react with hydroxyl radicals (produced photochemically) to produce peroxy radicals; peroxy radicals, in turn, react with NO to produce NO_2. The produced NO_2 then reacts further to produce ozone. As a result, Alberta's cities tend to act as ozone sinks due to elevated concentrations of NO_x from vehicle exhaust (Sandhu 1999). VOC by-products of these reactions may also react to produce ozone, multiplying the effects of the original VOC species with regard to ozone formation. Appendix 6 outlines the reaction mechanisms by which NO_x and VOCs react to form ozone.

The relative importance of a VOC on ozone formation depends on its tendency to react to form free radical species, and on the maximum amount of ozone produced by its reaction. These two concepts are collectively referred to as a substance's reactivity. Reactivity is quantified through the use of two different factors: the maximum incremental reactivity (MIR) and maximum ozone reactivity (MOR). The MIR and MOR for a VOC are determined experimentally using different nitrogen oxide (NOx) scenarios, and provide an indication of the amount of ozone produced as a result of increasing VOC emissions to an airshed (Carter 1994). In the MIR scenarios, NO_x inputs are adjusted to achieve the highest incremental reactivity, while in the MOR scenarios, the NO_x inputs are adjusted to yield the highest ozone concentration.

Previous work has been done to estimate the MIR and MOR values for a number of VOCs that favour the formation of ground-level ozone (Carter 1994, Carter 2000). These values have been established under laboratory conditions and, as such, do not represent VOC ozone formation potential under atmospheric conditions. Estimated MIR and MOR values are useful in determining the relative contribution of different VOCs toward ozone formation. Summaries of the compounds with the greatest MIR and MOR values are presented in Tables 5-4 and 5-5, respectively.

Table 5-4 VOCs which display the greatest maximum incremental reactivity

Compound or Mixture	MIR (g O_3 / g VOC)	
	Average	Standard Deviation
Biacetyl	20.73	3.02
Methacrylic Acid	18.78	2.47
Furan	16.54	2.32
2-Butyne	16.33	2.37
Methyl Glyoxal	16.21	2.37
Methyl Methacrylate	15.84	2.10
2-Methyl-2-Butene	14.45	1.86
Glyoxal	14.22	2.15
Trans 3-Methyl-2-Hexene	14.17	1.92
1-Methyl cyclopentene	13.95	1.94

Table 5-5 VOCs which display the greatest maximum ozone reactivity

Compound or Mixture	MOR ($g\ O_3$ / g VOC)	
	Average	Standard Deviation
Biacetyl	6.09	0.69
Methacrylic Acid	5.87	0.68
2-Butyne	5.30	0.76
Furan	4.97	0.73
Methyl Methacrylate	4.95	0.58
trans-2-Butene	4.89	0.66
1-Methyl cyclopentene	4.87	0.69
Trans 3-Methyl-2-Hexene	4.84	0.67
1,3-Butadiene	4.83	0.74
C4 Internal Alkenes	4.82	0.67

The MIR and MOR for a substance, although determined under laboratory conditions, can be made regionally applicable by factoring in ambient VOC concentrations. These values (expressed as mass of ozone produced) have been calculated for each hydrocarbon family at AENV ambient monitoring stations between 1990 and 2000 (Table A6-1). Table 5-6 presents average MIR and MOR values for each hydrocarbon family over the monitoring period. Reactivities used to calculate MIR and MOR values were based on a mechanism recently updated by Carter (2000). A similar study by Cheng *et al.* (1997) used reactivities from an earlier report by Carter (1994); therefore, it was not possible to perform direct numerical comparisons between the results of this study and those of Cheng *et al.* (1996).

Table 5-6 Average MIR and MOR values for VOCs at Alberta Environment monitoring stations between 1991 and 2000

Hydrocarbon Family	Edmonton East		Edmonton Central		Calgary Central	
	MIR ($\mu g\ O_3$ / g VOC)	MOR ($\mu g\ O_3$ / g VOC)	MIR ($\mu g\ O_3$ / g VOC)*	MOR ($\mu g\ O_3$ / g VOC)*	MIR ($\mu g\ O_3$ / g VOC)	MOR ($\mu g\ O_3$ / g VOC)
Alicyclics	23.73	13.30	9.45	5.14	8.77	4.76
Alkanes	286.31	175.72	95.81	58.48	89.39	54.25
Alkenes	128.18	49.14	131.58	49.12	134.11	51.49
Alkynes	4.62	1.79	9.10	3.55	9.46	3.69
Aromatics	104.60	31.54	139.28	43.02	142.08	43.96
Dienes	2.62	0.93	6.08	2.16	6.34	2.25

* Data from 1992 to 2000 for the Edmonton Central station.

At all sites, aromatics, alkanes and alkenes were the most important species in terms of ozone generation potential. The ozone generation potential of VOCs was found to be highest at Edmonton East, due to high concentrations of alkanes. These results are consistent with those of Cheng *et al* (1996).

5.2.2 Particulate Matter

Volatile organic compounds in the ambient atmosphere can affect human health and the environment both directly and indirectly through the formation of particulate matter. Particulate matter (PM) includes solid particles as well as liquid droplets that are suspended in air. The physical composition of particulate matter is most often categorized on the basis of particle size. The most common size categories are: less than or equal to 2.5 µm ($PM_{2.5}$); and, greater than 2.5µm but less than or equal to 10 µm (PM_{10}) in diameter.

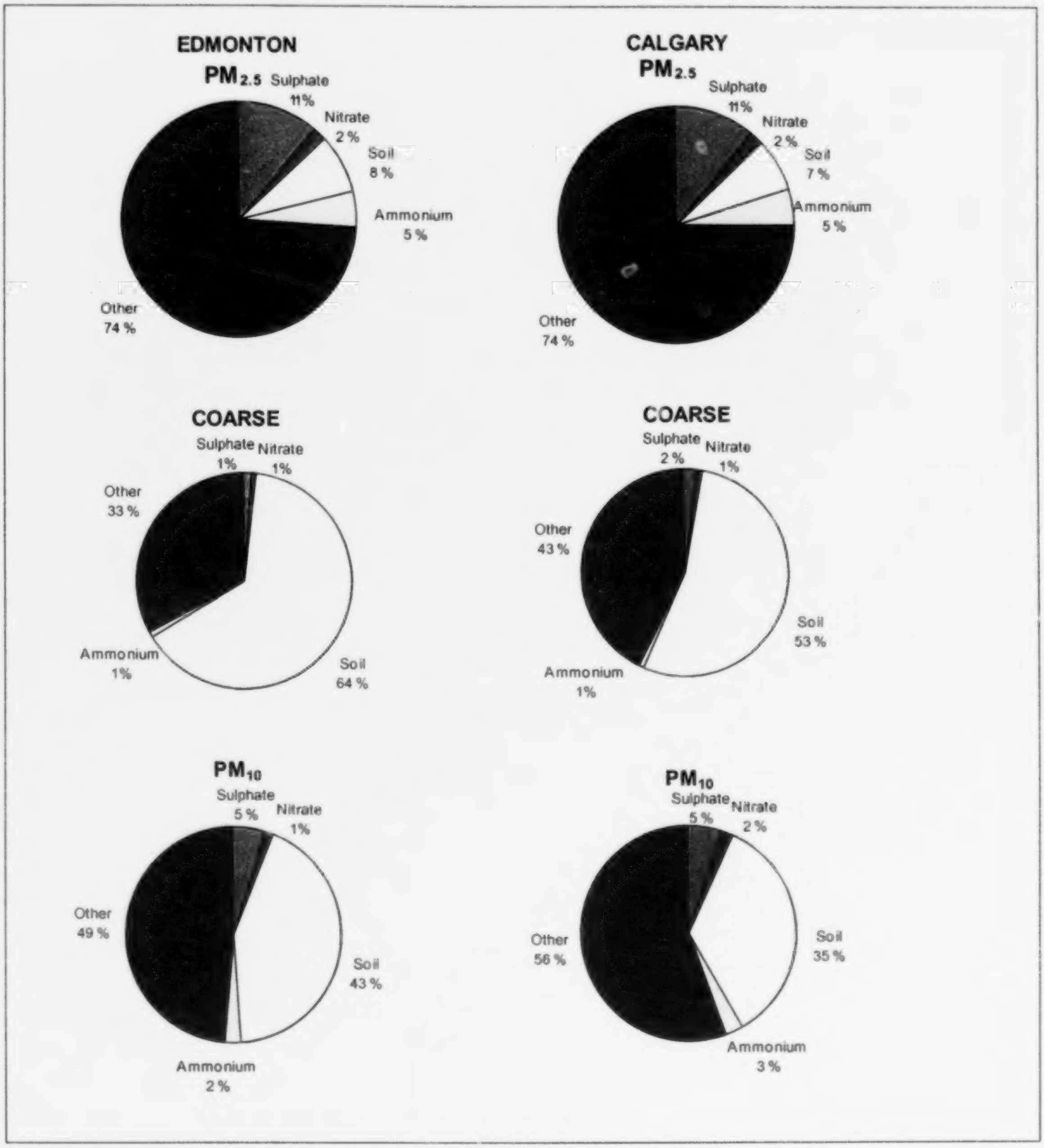
Elevated concentrations of PM_{10}, or coarse particulate matter, in the atmosphere are most commonly a result of direct natural emissions, primarily of materials derived from the earth's crust, such as soil and minerals (Health Canada 1998). Fine particulate matter ($PM_{2.5}$), on the other hand, may be caused partly by direct $PM_{2.5}$ emissions and partly by indirect, or secondary, formation from pollutants such as sulphur dioxide (SO_2), nitrogen oxides (NO_x), VOCs and ammonia (NH_3) (CWS DC 1999). Elevated levels of $PM_{2.5}$ are therefore usually the result of anthropogenic activities. The chemical and physical properties of PM depend on the geographical location, time of year and meteorological conditions at the time of formation (US EPA 2001*c*), as well as the nature of the source (i.e. natural or anthropogenic).

The effects of particulate matter on human health and the environment are dependent upon factors such as the size and chemical composition of particles. Fine particles have the potential to penetrate further into the lungs upon inhalation than coarse particles, and therefore pose a greater risk to human health (Health Canada 1998). In addition, fine particles are more likely to be formed from toxic or carcinogenic pollutants and, as such, pose an even greater risk to health. Exposure to particulate pollution has been linked with premature death, difficult breathing, aggravated asthma, increased hospital admissions and emergency room visits, and increased respiratory symptoms in children (US EPA 2001*c*). Environmental effects of increased particulate matter include reduced visibility and decreased growth and productivity of vegetation, due to interference with photosynthesis.

Volatile organic compounds may account for as much as 50% of total fine particle mass on average (Health Canada 1998). Few studies have examined the contribution of VOCs toward secondary particulate matter formation in Alberta. Cheng *et al* (1998) investigated the characteristics of fine PM in Edmonton and Calgary, Alberta over the period of 1985 to 1995 (Fig. 5-1); however, neither carbonaceous nor aqueous species were analyzed. As a result, it was not possible to determine the contribution of VOCs. The results of Cheng *et al* (1998) showed the mass apportionment of the "other" category to range from 33 to 74% for coarse PM and $PM_{2.5}$, respectively. VOC species may account for some percentage of the "other" category.

According to the Ontario Ministry of the Environment (MOE), alkenes and aromatics are the most important of the many VOC species with respect to fine particle formation (MOE 1999). The amount of a VOC that is converted to PM increases significantly with molar mass. As a result, the only VOCs to contribute significantly to PM formation are those that contain seven or more carbon atoms. In the case of alkenes, for example, isoprene (with five carbon atoms) is converted to PM to an insignificant extent, while *trans*-caryophyllene (with 15 carbon atoms) produces particles with yields of approximately 100% (MOE 1999).

The rates at which VOCs produce PM in the atmosphere are not well established. Rates may vary depending on the compound and ambient atmospheric conditions. Each VOC species in the atmosphere may produce other VOC species during reaction; therefore, the contribution of a compound to PM formation may be highly complex. Little research has been conducted regarding the relationship between $PM_{2.5}$, PM_{10} and organic constituents of particulate matter at Canadian locations.



NB: Percentages for a given pollutant may exceed 100, due to rounding.

Figure 5-1 **Mass apportionment of $PM_{2.5}$, coarse fraction of particulate matter and PM_{10} in Edmonton and Calgary for the period of 1985 to 1995 (Cheng *et al* 1998)**

6.0 APPROACHES TO VOC GUIDELINES

Alberta has ambient guidelines for a number of individual VOCs, as do several other jurisdictions. Many of these guidelines are based on such factors as human health endpoints, odour thresholds and ozone formation capacity. To date, none of these jurisdictions have dealt with total VOC in their guidelines. However, both total and individual VOC concentrations have been addressed in several jurisdictions' indoor air quality guidelines. Although exposure to VOC in indoor environments differs significantly from that experienced in outdoor environments, approaches used in developing indoor guidelines may be useful for setting an ambient guideline in Alberta. The following sections discuss approaches used in various jurisdictions with regard to ambient and indoor air quality guidelines for VOC.

6.1 Ambient Air Quality Guidelines

6.1.1 Alberta

Ambient air quality guidelines have been put in place in Alberta for over thirty substances, including several VOCs (AENV 2000). The guidelines, established under Section 14 of the *Environmental Protection and Enhancement Act* (EPEA), are part of the Alberta air quality management system. The Alberta Ambient Air Quality Guidelines for selected VOCs can be found in Table 6-1.

With the exception of ethylene, ethylene oxide and formaldehyde, all of the ambient guidelines for VOC substances were based on the Texas Effects Screening Level (ESL) for each substance. The ESLs were developed on the basis of health effect thresholds, odour nuisance potential, vegetative effects and corrosion. Ethylene, ethylene oxide and formaldehyde guidelines were based on Ontario's Point of Impingement (POI) Standards; the POIs for these three substances were developed on the basis of vegetative effects, health effect thresholds and odour nuisance potential, respectively.

6.1.2 Other Jurisdictions in Canada

In addition to the guidelines developed by Alberta Environment, ambient air guidelines have been developed by the Ontario Ministry of the Environment (MOE) and the Government of Québec. These criteria have been put in place for a wide range of chemical substances, and are based on such factors as health effects, odour, ozone formation capacity and negative impacts on vegetation.

The Ontario MOE has developed ambient air quality criteria (AAQC) for more than 300 substances, including some 231 VOC species (Table A7-1; MOE 2001), and corresponding point of impingement (POI) standards and guidelines for the majority of these substances. AAQC are used by the Ministry for assessment of general air quality and the potential for causing an adverse effect. Compounds that are known carcinogens have not been given standard or guideline values, as they are considered dangerous to human health at any level of exposure. Table A7-1 presents the Ontario AAQC, along with the limiting effects used to determine the values. POI standards and guidelines are used in reviewing applications for certificates of approval for emissions to air (MOE 2000).

Table 6-1 Alberta Ambient Air Quality Guidelines for volatile organic compounds

Substance	Guideline 1-hour average ($\mu g/m^3$)	Guideline 1-hour average (ppbv)*
Acetaldehyde	90	50
Acetic Acid	250	102
Acetone	5900	2400
Benzene	30	9
Dimethyl ether	19100	10100
Ethyl chloroformate	0.57	0.13
Ethylene	120 (6-hour average) 50 (30-day)	104 (6-hour average) 43 (30-day)
Ethylene oxide	15 (30-minute average)	8 (30-minute average)
Formaldehyde	65	53
Methanol	2600	2000
Methylene bisphenyl diisocyanate	0.51	0.05
Monoethylamine	1.19	0.6
Phenol	100	26
Phosgene	4	1
Styrene	215	52
Vinyl chloride	130	51

* Standard conditions of 25°C and 101.325 kPa are used as the basis for conversion from $\mu g/m^3$ to ppbv (parts per billion by volume) or from mg/m^3 to ppmv (parts per million by volume).

AAQC were first developed in Ontario more than 20 years ago. The process by which these criteria were developed appears to have been based largely on a review of guidelines in other jurisdictions. The MOE is currently in the process of reviewing and updating existing air quality criteria to ensure that they are current and protective of human and ecosystem health. The substances for which guideline values are currently being reviewed are presented in Table 6-2.

Table 6-2 **Substances currently under review for ambient air quality criteria setting in Ontario**

Contaminant	Existing	Amendment
Contaminants to be changed		
Ethyl benzene	4,000 (S)	3,000*
Methanol	84,000 (S)	12,000
Methyl ethyl ketone	31,000 (S)	30,000*
Trichloroethylene	85,000 (S)	3,500*
Contaminants to be added		
Acrylonitrile	300 (G)	180*
Chloroform	1,500 (G)	300*
Ethyl ether	30,000 (G)	7,000*
n-Heptane	-	33,000*
Isopropyl benzene	100 (G)	100
Methyl isobutyl ketone	1,200 (G)	1,200
Mineral spirits	30,000 (G)	7,800*
Propylene oxide	13,500 (G)	450*
Vinylidene chloride	70 (G)	30
Standards (no change)		
Ammonia	3,600 (S)	3,600*
Chlorine	300 (S)	300*
Hydrogen Chloride	100 (S)	100*
Toluene	2,000 (S)	2,000
Xylenes	2,300 (S)	2,300

(S) – current standard, (G) – current guideline
*Interim standard, subject to re-evaluation through Risk Management Framework

The Government of Québec Ministry of the Environment has also developed air quality criteria and provisional management criteria for over 700 air contaminants (Tables A7-2 and A7-3; Environnement Québec 1999). Air quality criteria are legislated standards, while provisional management criteria are temporary, recommended guidelines. These criteria have been based on the results of a review of guidelines used by environmental agencies around the world, as well as gathered toxicological data. Sources of information used by the Ministry include the US EPA, the US Public Health Service, the United Nations Environment Program and the California Environmental Protection Agency, among others. Twenty-four hour management criteria for the majority of substances are the same as ambient air quality criteria developed for the same substances by the Government of Ontario.

6.1.3 United States

The US EPA, in accordance with the Clean Air Act, has set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. To date, the EPA Office of Air Quality Planning and Standards has set NAAQS for a total of six principal pollutants, including carbon monoxide, nitrogen dioxide, ozone, lead, PM_{10}, $PM_{2.5}$ and sulphur dioxide. No standards have been developed for total or individual VOC compounds. Regulation of VOCs and other atmospheric contaminants is considered the responsibility of individual states.

The Texas Natural Resource Conservation Commission (TNRCC) has developed Effects Screening Levels (ESLs) for a number of substances. The ESLs are intended to act as an instrument for evaluating the potential for effects to occur as a result of exposure to these substances (TNRCC 2001). To date, ESLs have been developed for over 1900 substances. The levels are based on data concerning health effects, odour nuisance potential, vegetative effects and corrosion effects. Most contaminants have been given both short-term (one-hour average) and long-term (annual average) effects screening levels. The Texas ESLs are presented in Table A7-4.

Although the Effects Screening Levels are not Ambient Air Quality Standards, they indicate concentrations at which extra attention should be given to a contaminant's presence in the atmosphere. For example, a contaminant that exists at a concentration lower than its ESL is not expected to result in adverse human health effects. On the other hand, if the ambient concentration of a contaminant exceeds its respective ESL, a more extensive review is conducted into that contaminant's presence; this scenario is not necessarily indicative of the existence of problematic concentrations.

6.1.4 International

The World Health Organization (WHO) has created guidelines for a number of atmospheric contaminants. The WHO Air Quality Guidelines for Europe were first published in 1987 (WHO 1987) and have been revised most recently in 2000 (WHO 2000). The goal of developing these guidelines has been to provide a basis for protecting public health from the adverse effects of air pollutants. The guidelines are intended to provide background information and guidance to international, national and local authorities in making risk assessment and risk management decisions. Values are included for both inorganic and organic chemicals. Several individual VOCs are included, but no group (total VOC) value is provided. Values provided in the WHO document represent the minimum exposure level at which each of the noted contaminants has been shown to pose a risk to human health. A complete listing of WHO guideline values and tolerance concentrations (health-based), as of the final revision in 2000, can be found in Tables A7-5 and A7-6.

The WHO guidelines are largely based on acceptable risk levels rather than absolute safety (zero risk), as insufficient data exists for the purpose of setting guidelines based on absolute safety. Research by the WHO in setting the guidelines included considering current levels of human exposure from all sources, toxicokinetics and contributions from air in relation to other sources. The first step taken for compounds with no direct carcinogenic effects was to determine their highest and lowest concentrations at which there are no adverse effects (No Observed Adverse Effect Level (NOAEL) and Lowest Observed Adverse Effect Level (LOAEL)) in humans, animals or plants. It was noted in the WHO document that the LOAEL is more easily related to levels of exposures of concern in humans than is the NOAEL; therefore, the LOAEL was used whenever possible. Compounds with carcinogenic endpoints were evaluated using a two-step procedure. The first step was to conduct a qualitative assessment of the likelihood of that compound being a human carcinogen. The second step was a quantitative assessment of the cancer risk likely to occur at a given level and duration of exposure. The WHO recommends that regulatory agencies take into consideration such factors as technical, social, economic and cultural conditions when setting air quality standards.

6.2 Indoor Air Quality Guidelines

Indoor air quality issues are complex, due to the many factors that may cause concentrations and effects of VOCs to vary from one building to another, such as the age of the building, the building materials used, whether or not the occupants smoke tobacco products, the ages of the occupants, and the activities performed indoors. The following sections outline some of the indoor VOC concentration guidelines that have been developed by various agencies.

6.2.1 Health Canada

In 1987, Health Canada developed guidelines for indoor concentrations of selected contaminants (Health Canada 1987). Although they are not mandatory or enforceable as standards, they are intended to assist individuals and public agencies in making consistent judgements about the need for remedial measures. Of these contaminants, aldehydes were the only group of VOC addressed. The aldehyde guideline, designed for cases in which more than one aldehyde is detected in indoor air, is represented by the formula:

$$c_1/C_1 + c_2/C_2 + c_3/C_3$$

The sum of these terms should not exceed 1, where **c1**, **c2** and **c3** are the concentrations of formaldehyde, acrolein and acetaldehyde, respectively, as measured over a five-minute period, and C_1, C_2 and C_3 are as follows:

C_1 (formaldehyde) - 120 μg/m 3 (0.10 ppm);

C_2 (acrolein) - 50 μg/m 3 (0.02 ppm);

C_3 (acetaldehyde) - 9000 μg/m 3 (5.0 ppm).

Because formaldehyde is anticipated to be a human carcinogen, Health Canada also developed exposure guidelines for formaldehyde in residential indoor air. At the time the guidelines were created, an action level of 120 $\mu g/m^3$ (0.10 ppm) was considered the lowest achievable concentration. However, it was recommended that indoor concentrations be reduced below 60 $\mu g/m^3$ (0.05 ppm) in the future.

6.2.2 Commission of the European Communities

Since 1987, the Commission of the European Communities (CEC) has collaborated with a multidisciplinary group of European scientists, with the ultimate goal of providing healthy and environmentally sustainable buildings. In the report entitled *Guidelines for Ventilation Requirements in Buildings* (CEC 1992), the CEC makes recommendations for total volatile organic compound exposure guidelines, based the work of Seifert (1990) for non-industrial indoor environments. Seifert's proposal for total VOC guidelines addresses the ten most prevalent compounds in each of seven hydrocarbon classes, including alkanes, aromatic hydrocarbons, terpenes, halocarbons, esters, aldehydes, ketones, and "other", or miscellaneous compounds. According to the report, the concentrations in each of these classes should be below the maximum concentrations listed in Table 6-3, based on 96-hour adjusted concentrations and an air change rate of 0.5 hr^{-1}.

Table 6-3 Total VOC exposure guidelines recommended by the Commission of the European Communities (CEC 1992)

Substance	**Exposure Guideline 96-hr average ($\mu g/m^3$)**
Alkanes	100
Aromatic hydrocarbons	50
Terpenes	30
Halocarbons	30
Esters	20
Aldehydes and ketones (excluding formaldehyde)	20
Other	50
Sum of VOC	**300**

The total VOC concentration is calculated by adding the totals from each class. The CEC gives a target total VOC concentration of 300 $\mu g/m^3$, which is the sum of the above listed target concentrations. One condition placed on these guidelines is that no individual compound concentration should exceed 50 percent of the guideline for its class or 10 percent of the total VOC target guideline concentration. Seifert emphasizes that the proposed guideline is not based on toxicological considerations, but on levels that could reasonably be achieved considering the amount of indoor concentration information available at the time of the study (Seifert 1990). Additionally, Seifert acknowledges the possibility that guidelines may need to be developed for individual VOC species.

6.2.3 Health Council of the Netherlands

In 2000, the Health Council of the Netherlands prepared a report to determine the volatile organic compounds that may be emitted from building materials or other sources into the indoor environment (Health Council of the Netherlands 2000). As part of their analysis, the council examined approaches to setting a limit value for VOC in indoor air. The conclusion reached was that chemo-sensoric reactions may be considered a useful biological basis for determining the limit value. The relevant VOC concentration in indoor air was estimated to be 200 $\mu g/m^3$. This approach does not take into account the health risks that can be attributed to individual VOCs. The council recommends that emissions of any carcinogenic, reprotoxic or sensitizing substance be reduced to the lowest level possible.

7.0 CONCLUSION

Volatile organic compounds are present in Alberta's air as the result of emissions from many biogenic and anthropogenic sources. While biogenic sources account for approximately 62% of total provincial emissions, anthropogenic sources are responsible for emitting a different suite of VOCs, which may be more important in terms of photochemical oxidation. Emissions from the industrial and transportation sectors contribute most significantly toward anthropogenic emissions in Alberta.

Ambient VOCs are monitored at a number of sites across Alberta, including both urban and rural locations. Trend analyses from Alberta Environment station data have shown decreased ambient levels of alkanes, dienes and aromatic compounds between 1991 and 2000. Concentrations of alkanes and alicyclic compounds are shown to be higher, on average, at the urban industrial site than at the other urban sites, while alkynes and dienes are present at lower concentrations.

There are several approaches that could be used in the development of a total VOC guideline. These approaches are based on the following factors:

- toxicity (carcinogenic and non-carcinogenic effects);
- odour and annoyance;
- ozone formation capacity; and,
- contribution to ambient particulate matter formation.

Several jurisdictions, including Alberta, have developed Ambient Air Quality Guidelines for individual VOC species based on some of these approaches. To date, none of these jurisdictions have dealt with total VOCs in their guidelines; however, both total and individual VOC concentrations have been addressed in several jurisdictions' indoor air quality guidelines.

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9.0 APPENDICES

Appendix 1: Anthropogenic VOC Emissions in Alberta

Table A1-1 **Anthropogenic VOC emissions in Alberta and Canada in 1995 (Environment Canada 2001*a*)**

Category / Sector	Alberta (t)	Canada (t)
Abrasives Manufacture		1 481
Aluminum Industry		963
Asbestos Industry		1
Asphalt Paving Industry		3 318
Bakeries	313	6 005
Cement and Concrete Industry	36	438
Chemicals Industry	2 027	9 403
Clay Products Industry		3
Coal Mining Industry	589	1 762
Ferrous Foundries	1	1 807
Grain Industries		2
Iron and Steel Industries	1	28 277
Iron Ore Mining Industry		839
Mining and Rock Quarrying	14	688
Non-Ferrous Mining and Smelting Industry		75
Oil Sands	81	81
Other Petroleum and Coal Products Industry		88
Paint & Varnish Manufacturing		1 957
Petrochemical Industry	8 528	16 523
Petroleum Refining	755	47 655
Plastics & Synthetic Resins Fabrication		6 684
Pulp and Paper Industry	43	23 283
Upstream Oil and Gas Industry	484 788	689 393
Wood Industry	11	47 100
Other Industries	309	52 995
TOTAL INDUSTRIAL SOURCES	**497 497**	**940 821**
Commercial Fuel Combustion	260	1 730
Electric Power Generation (Utilities)	1 101	2 980
Residential Fuel Combustion	511	2 311
Residential Fuel Wood Combustion	36 033	400 092
TOTAL NON INDUSTRIAL FUEL COMBUSTION	**37 905**	**407 112**
Air Transportation	2 050	11 636
Heavy-duty diesel vehicles	8 178	48 540
Heavy-duty gasoline trucks	2 444	11 814
Light-duty diesel trucks	680	2 600
Light-duty diesel vehicles	49	747
Light-duty gasoline trucks	28 982	142 425
Light-duty gasoline vehicles*	44 123	355 873
Marine Transportation	2 853	37 449
Motor cycles	171	2 027
Off-road use of diesel	5 608	22 581

Category / Sector	**Alberta (t)**	**Canada (t)**
Off-road use of gasoline	11 769	93 111
Rail Transportation	1 039	5 608
Tire wear & Brake lining		
TOTAL TRANSPORTATION	**107 946**	**734 412**
Crematorium		
Industrial & Commercial Incineration	3	690
Municipal Incineration		703
Wood Waste Incineration	1 068	4 568
Other Incineration & Utilities		294
TOTAL INCINERATION	**1 071**	**6 255**
Cigarette Smoking	1	8
Dry Cleaning	753	7 832
Fuel Marketing	9 678	98 498
General Solvent Use	26 584	274 926
Marine Cargo Handling Industry		1
Meat Cooking		
Pesticides and Fertilizer Application		66
Printing	2 633	29 058
Structural Fires	585	5 147
Surface Coatings	10 606	134 194
TOTAL MISCELLANEOUS	**50 840**	**549 731**
Agriculture (Animals)		12 982
Agriculture Tilling and Wind Erosion		
Construction Operations		
Dust from Paved Roads		
Dust from Unpaved Roads		
Forest Fires	61 356	902 444
Landfills Sites	309	5 139
Mine Tailings		0
Prescribed Burning	5 808	16 306
TOTAL OPEN SOURCES	**67 473**	**936 871**
TOTAL WITH OPEN SOURCES	**762 732**	**3 575 202**
TOTAL WITHOUT OPEN SOURCES	**695 259**	**2 638 331**

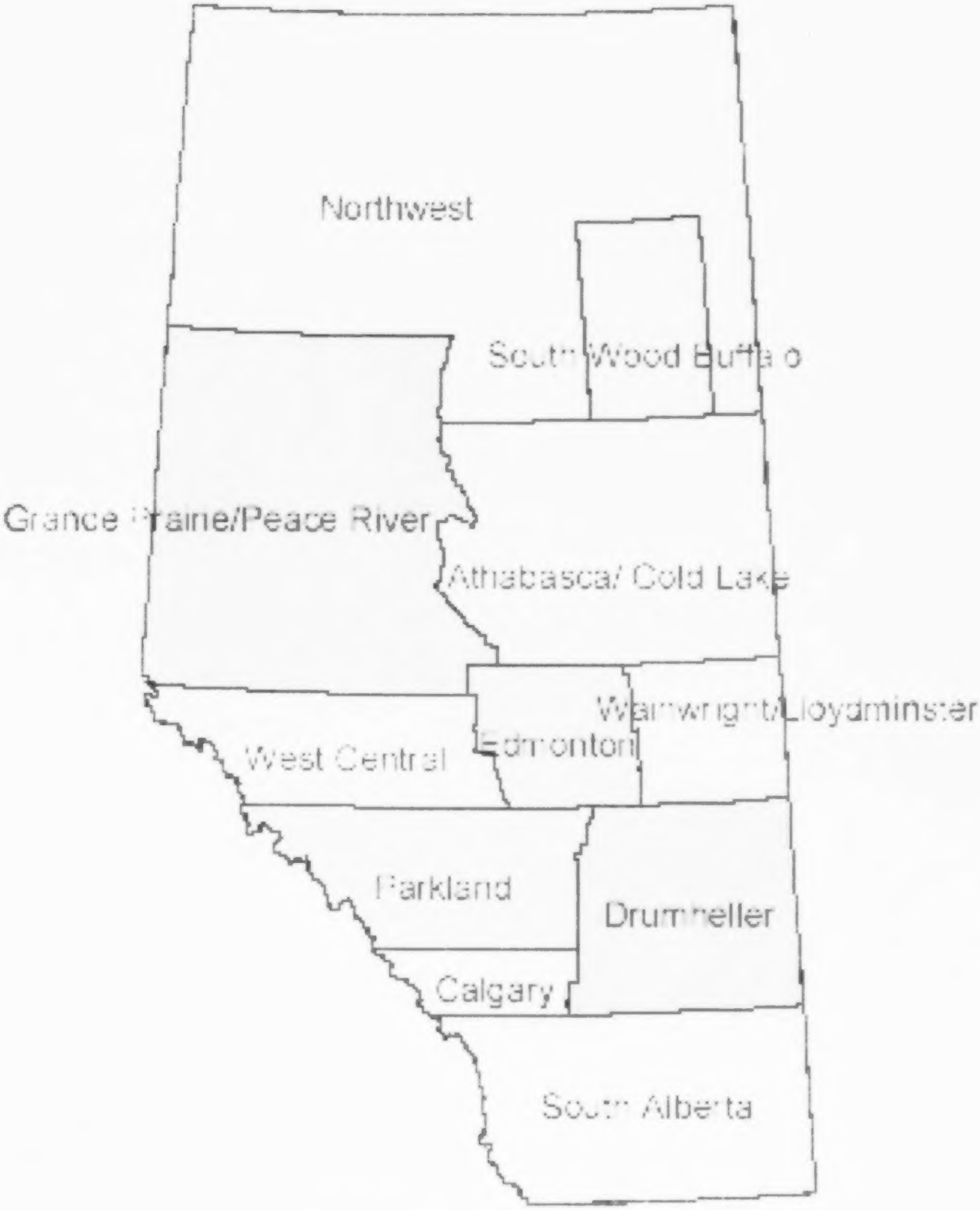
Northwest
South Wood Buffalo
Grande Prairie/Peace River
Athabasca/ Cold Lake
Wainwright/Lloydminster
Edmonton
West Central
Parkland
Drumheller
Calgary
South Alberta

Figure A1-1 Airshed boundaries in Alberta, as defined by the Multi-Stakeholder Group for Particulate Matter and Ozone (Alberta MSG 1999)

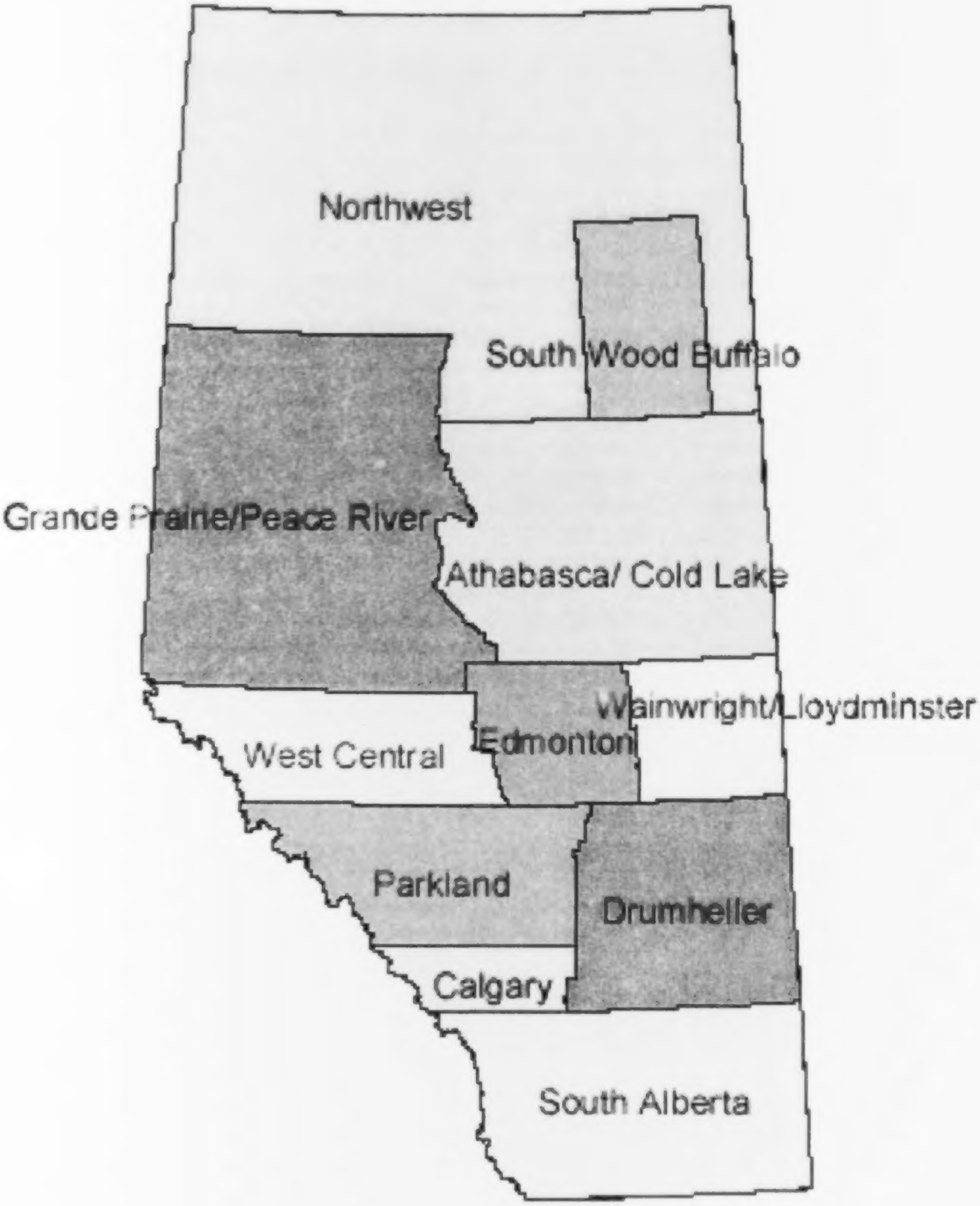
Northwest
South Wood Buffalo
Grande Prairie/Peace River
Athabasca/ Cold Lake
Wainwright/Lloydminster
West Central
Edmonton
Parkland
Drumheller
Calgary
South Alberta

Figure A1-1 **Airshed boundaries in Alberta, as defined by the Multi-Stakeholder Group for Particulate Matter and Ozone (Alberta MSG 1999)**

Table A1-2 Sectoral VOC emissions in Alberta's airsheds (as defined by Alberta MSG 1999)

Airshed	Industrial Sources (t)	Non-Industrial Fuel Combustion (t)	Transportation (t)	Incineration (t)	Miscellaneous (t)	Open Sources (t)	Total (t)
West Central	23,798	632	8,107	141	833	3	33,514
Parkland	48,931	2,407	11,214	64	3,093	13	65,722
South Wood Buffalo	36,578	438	397	17	441	4,108	41,979
Edmonton	79,075	13,796	34,653	147	18,822	126	146,619
Calgary	166,402	11,895	20,136	92	17,436	116	216,077
South Alberta	37,073	3,433	17,067	34	4,383	19	62,009
Drumheller	17,741	1,125	4,883	12	816	6	24,583
Wainwright / Lloydminster	17,045	898	7,183	11	910	6	26,053
Grande Prairie / Peace River	43,162	1,802	2,331	321	2,446	1,431	51,493
Athabasca / Cold Lake	23,540	1,250	1,516	134	1,393	25,612	53,445
Northwest	4,126	229	451	98	265	36,034	41,203
Alberta Total	497,471	37,905	107,938	1,071	50,838	67,474	762,697

Appendix 2: Biogenic VOC Emissions in Alberta

Table A2-1 1995 Biogenic VOC emissions in Canada by province/territory (Environment Canada 2001*b*)

Province	Total VOC (t)	National Contribution	Surface Area (km^2)	VOC Emission Density (t/km^2)
Newfoundland	425,665	3.33%	338,758	1.26
Prince Edward Island	7,433	0.06%	5,480	1.36
Nova Scotia	161,670	1.27%	54,060	2.99
New Brunswick	205,254	1.61%	71,220	2.88
Québec	2,116,635	16.58%	1,085,153	1.95
Ontario	2,199,000	17.22%	935,610	2.35
Manitoba	1,005,300	7.87%	554,025	1.81
Saskatchewan	1,002,541	7.85%	590,497	1.70
Alberta	1,235,410	9.67%	614,104	2.01
British Columbia	2,428,624	19.02%	790,870	3.07
Yukon Territory	807,784	6.33%	393,819	2.05
Northwest Territories	1,174,194	9.20%	1,522,135	0.77
Canada	12,769,510		6,955,731	1.84

Table A2-2 **Area-based emission factors of different vegetation types, calculated using Biogenic Emission Inventory System (BEIS2) Model (Man and Kharrat 2000)**

Natural Region	Vegetation	Isoprene ($\mu g/m^2/hr$)	Monoterpenes ($\mu g/m^2/hr$)	Other VOCs ($\mu g/m^2/hr$)	Total VOCs ($\mu g/m^2/hr$)
Boreal Mixedwood	Conifer	22247	1255	7622	**31124**
	Deciduous	25539	639	9687	**35865**
	Mixedwood	23893	947	8654	**33494**
	Pasture	2140	143	2885	**5168**
	Urban areas	1384	67	923	**2374**
Foothills	Conifer	26216	1514	8973	**36703**
	Deciduous	29003	733	11046	**40782**
	Mixedwood	27610	1124	10009	**38743**
	Pasture	2680	179	3604	**6463**
	Urban areas	1640	81	1121	**2842**
Rocky Mountains	Conifer	25486	1696	8656	**35838**
	Deciduous	18117	466	6874	**25457**
	Mixedwood	21801	1081	7765	**30647**
	Pasture	2106	163	2020	**4289**
	Urban areas	1293	76	715	**2084**
Grassland	Pasture	1083	72	1489	**2644**
	Urban areas	1172	52	644	**1868**
Parkland	Pasture	2041	135	2806	**4982**
	Urban areas	1364	65	907	**2336**
Province	Crop	14	12	12	**38**

Appendix 3: Ambient VOC Monitoring in Alberta

Table A3-1 Characteristics of ambient monitoring stations in Alberta

Monitoring Site	Operator	Parameter	Monitoring Frequency	Time Period
Edmonton Central	AENV	VOC	Intermittent (6 days)	May 1991 – present
Edmonton Central	AENV	THC**	Continuous	May 1991 – present
Edmonton East	AENV	VOC	Intermittent (6 days)	Aug. 1990 – present
Edmonton East	AENV	THC	Continuous	Aug. 1990 – present
Edmonton Northwest	AENV	THC	Continuous	1991 – present
Calgary Central	AENV	VOC	Intermittent (6 days)	Aug. 1990 - present
Calgary Central	AENV	THC	Continuous	Aug. 1990 - present
Calgary East	AENV	THC	Continuous	1991 – present
Calgary Northwest	AENV	THC	Continuous	1991 – present
Athabasca Valley	AENV	THC	Continuous	1991 – 1997
Fort Saskatchewan (100 Ave & 98 St)	AENV	THC	Continuous	1992
Fort Saskatchewan (9209A - 96 Ave)	AENV	THC	Continuous	1993 – present
Red Deer	AENV	THC	Continuous	1999 – present
Sherwood Park	AENV	THC	Continuous	1997 – 2000
Athabasca Valley	WBEA	VOC	Intermittent (2 weeks)	Aug. 1998 - present
Athabasca Valley	WBEA	THC	Continuous	1997 - present
Patricia McInnes	WBEA	VOC	Intermittent (2 weeks)	Aug. 1998 - present
Patricia McInnes	WBEA	THC	Continuous	1998 – present
Fort McKay	WBEA	VOC	Intermittent (2 weeks)	Aug. 1998 - present
Fort McKay	WBEA	THC	Continuous	1998 – present
Barge Landing	WBEA	VOC	Intermittent (1 week)	Oct. 2000 – present

Buffalo Viewpoint	WBEA	THC	Continuous	1998 – present
Lower Camp	WBEA	THC	Continuous	1998 – present
Mannix	WBEA	THC	Continuous	1998 – present
Mildred Lake	WBEA	THC	Continuous	1998 – present
Violet Grove	WCAS	BTEX[*]	Intermittent	Feb. – Dec. 2000
Violet Grove	WCAS	THC	Continuous	Feb. – Dec. 2000
Caroline	PAMZ	THC	Continuous	Aug. 2000 - present
Leslieville	PAMZ	THC	Portable (Continuous)	Mar. – Apr. 2001, Sept. 2001 - present
Alix	PAMZ	THC	Portable (Continuous)	Oct. – Nov. 2000, Apr. – May 2001
Crossfield	PAMZ	THC	Portable (Continuous)	Nov. – Dec. 2000, Feb. – Mar. 2001, May 2001, Sept. 2001
Rimbey	PAMZ	THC	Portable (Continuous)	Dec. 2000 – Jan. 2001
Sundre	PAMZ	THC	Portable (Continuous)	Jan. – Feb. 2001, Aug. 2001

[*] BTEX – Benzene, Toluene, Ethylbenzene and Xylenes (m/p- and o- isomers)

[**] THC – Total Hydrocarbons

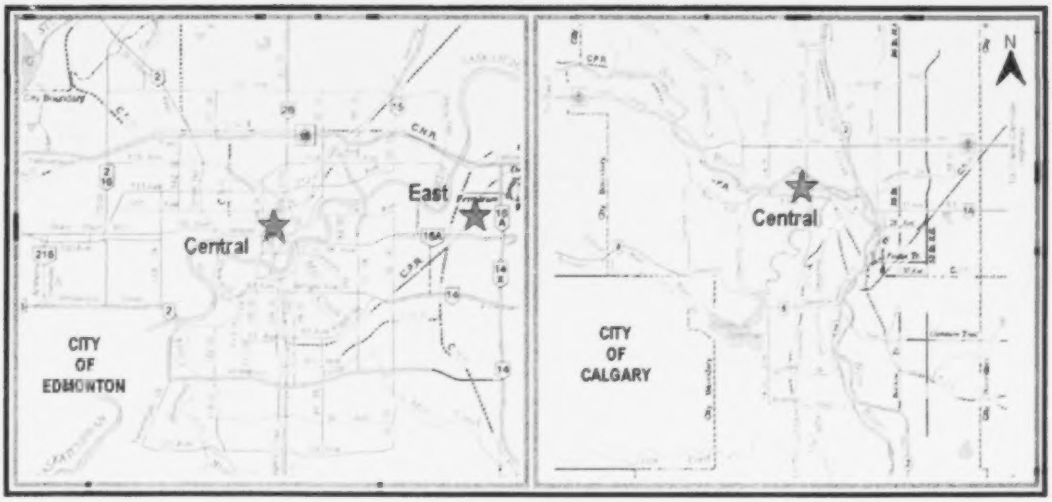
Central
East
CITY OF EDMONTON
Central
CITY OF CALGARY
N

Figure A3-1 Locations of the Alberta Environment ambient VOC monitoring stations

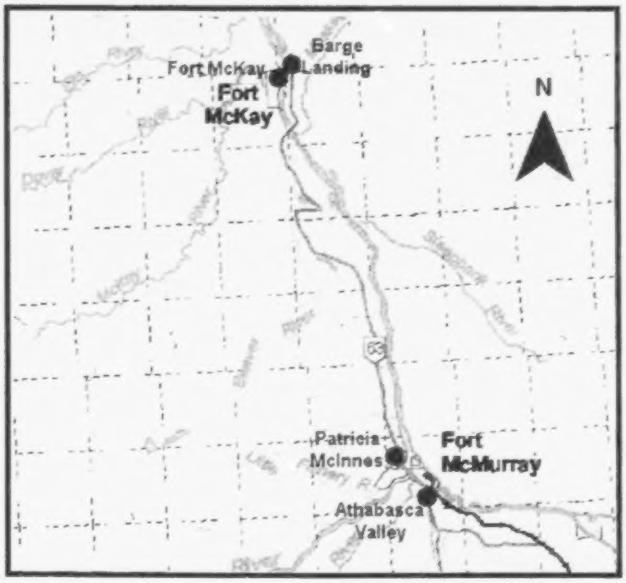
Barge Landing
Fort McKay
Fort McKay
N
63
Patricia McInnes
Fort McMurray
Athabasca Valley

Figure A3-2 Map of VOC monitoring stations in the Wood Buffalo Region

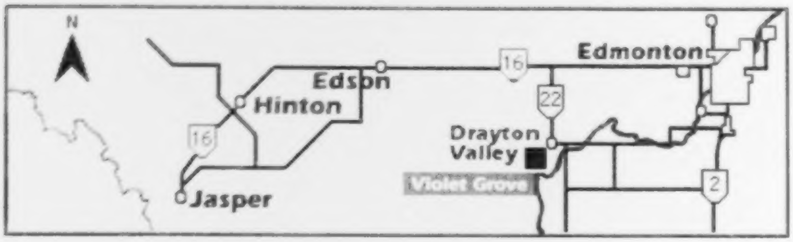
N
Edmonton
Edson
Hinton
16
16
22
Drayton Valley
Violet Grove
2
Jasper

Figure A3-3 Location of the Violet Grove ambient VOC monitoring station in the West Central Airshed Zone

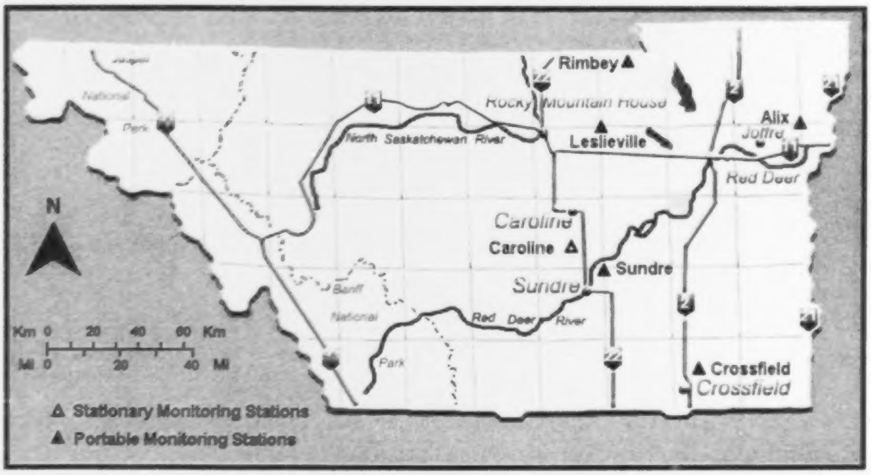
Rimbey ▲
Rocky Mountain House
▲
Leslieville
Alix ▲
Joffre
Red Deer
National
Park
North Saskatchewan River
N
Caroline
Caroline △
▲ Sundre
Sundre
Banff
National
Park
Red Deer River
Km 0 20 40 60 Km
Mi 0 20 40 Mi
▲ Crossfield
Crossfield
△ Stationary Monitoring Stations
▲ Portable Monitoring Stations

Figure A3-4 Ambient VOC monitoring stations in the Parkland Airshed Management Zone

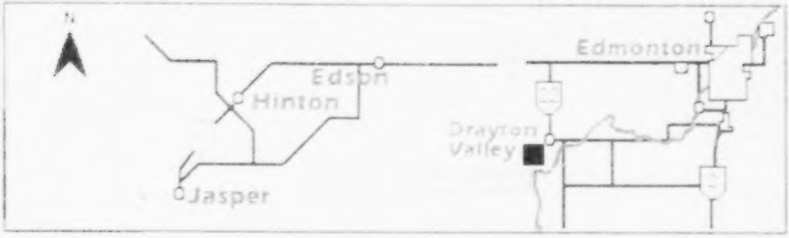
N
Edmonton
Edson
Hinton
Drayton Valley
Jasper

Figure A3-3 Location of the Violet Grove ambient VOC monitoring station in the West Central Airshed Zone

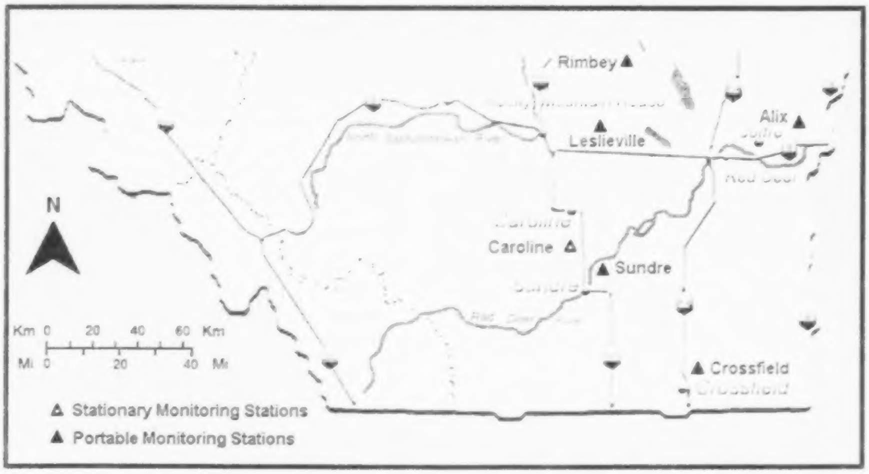
Rimbey
Leslieville
Alix
N
Caroline
Sundre
Km 0 20 40 60 Km
Mi 0 20 40 Mi
Crossfield
Crossfield
△ Stationary Monitoring Stations
▲ Portable Monitoring Stations

Figure A3-4 Ambient VOC monitoring stations in the Parkland Airshed Management Zone

Table A3-2 VOC species analyzed at AENV monitoring stations

1,1,1-Trichloroethane	2,2,4-Trimethylpentane	4-Methylheptane	Cyclopentane	n-Butylbenzene
1,1,2,2-Tetrachloroethane	2,2,5-Trimethylhexane	4-Methyloctane	Cyclopentene	Nonane
1,1,2-Trichloroethane	2,2-Dimethylbutane	Acetylene	Decane	n-Propylbenzene
1,1-Dichloroethane	2,2-Dimethylhexane	Benzene	Dibromochloromethane	Octane
1,1-Dichloroethylene	2,2-Dimethylpentane	Benzylchloride	Dibromomethane	o-Xylene
1,2,3-Trimethylbenzene	2,2-Dimethylpropane	Bromochloromethane	Dichloromethane	p-Cymene
1,2,4-Trichlorobenzene	2,3,4-Trimethylpentane	Bromodichloromethane	Dodecane	Pentane
1,2,4-Trimethylbenzene	2,3-Dimethylbutane	Bromoform	EDB	Propane
1,2-Dichlorobenzene	2,3-Dimethylpentane	Bromomethane	Ethane	Propylene
1,2-Dichloroethane	2,4-Dimethylhexane	Bromotrichloromethane	Ethylbenzene	sec-Butylbenzene
1,2-Dichloropropane	2,4-Dimethylpentane	Butane	Ethylbromide	Styrene
1,2-Diethylbenzene	2,5-Dimethylheptane	Carbontetrachloride	Ethylene	tert-Butylbenzene
1,3,5-Trimethylbenzene	2,5-Dimethylhexane	Chlorobenzene	Freon11	Tetrachloroethylene
1,3-Butadiene	2-Ethyl-1-Butene	Chloroethane	Freon113	Toluene
1,3-Dichlorobenzene	2-Ethyltoluene	Chloroform	Freon114	trans-1,2-Dichloroethylene
1,3-Diethylbenzene	2-Methyl-1-butene	Chloromethane	Freon12	trans-1,2-Dimethylcyclohexane
1,4-Dichlorobenzene	2-Methyl-1-Pentene	cis-1,2-Dichloroethylene	Freon22	trans-1,3-Dichloropropene
1,4-Dichlorobutane	2-Methyl-2-butene	cis-1,2-Dimethylcyclohexane	Heptane	trans-1,4-Dimethylcyclohexane
1,4-Diethylbenzene	2-methyl-2-Pentene	cis-1,3-Dichloropropene	Hexachlorobutadiene	trans-2-Butene
1-Butene/Isobutene	2-Methylheptane	cis-1,3-Dimethylcyclohexane	Hexane	trans-2-Heptene
1-Butyne	2-Methylhexane	cis-1,4/t-1,3-Dimethylcyclohexane	Hexylbenzene	trans-2-Hexene
1-Decene	2-Methylpentane	cis-2-Butene	Indane	trans-2-Octene
1-Heptene	3,6-Dimethyloctane	cis-2-Heptene	Isobutane	trans-2-Pentene
1-Hexene	3-Ethyltoluene	cis-2-Hexene	iso-Butylbenzene	trans-3-Heptene
1-Methylcyclohexene	3-Methyl-1-pentene	cis-2-Octene	Isopentane	trans-3-Methyl-2-pentene
1-Methylcyclopentene	3-Methylheptane	cis-2-Pentene	Isoprene	trans-4-Methyl-2-pentene
1-Nonene	3-Methylhexane	cis-3-Heptene	iso-Propylbenzene	Trichloroethylene
1-Octene	3-Methyloctane	cis-3-Methyl-2-pentene	m and p-Xylene	Undecane
1-Pentene	3-Methylpentane	cis-4-Methyl-2-pentene	Methylcyclohexane	Vinylchloride
1-Propyne	4-Ethyltoluene	Cyclohexane	Methylcyclopentane	
2,2,3-Trimethylbutane	4-Methyl-1-pentene	Cyclohexene	Naphthalene	

Table A3-3 Mean and maximum VOC concentrations measured at Edmonton East, Edmonton Central and Calgary Central in 2000

Compound	Edmonton East		Edmonton Central		Calgary Central	
	Mean (μg/m^3)	Max (μg/m^3)	Mean (μg/m^3)	Max (μg/m^3)	Mean (μg/m^3)	Max (μg/m^3)
1,1,1-Trichloroethane	0.34	0.92	0.40	0.50	0.35	0.45
1,1,2,2-Tetrachloroethane	0.05	0.08	0.05	0.09	0.05	0.08
1,1,2-Trichloroethane	0.05	0.15	0.04	0.08	0.04	0.07
1,1-Dichloroethane	0.04	0.13	0.04	0.06	0.04	0.06
1,1-Dichloroethylene	0.06	0.10	0.07	0.10	0.06	0.09
1,2,3-trimethylbenzene	0.30	0.88	0.37	0.78	0.38	1.62
1,2,4-Trichlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00
1,2,4-trimethylbenzene	1.00	3.05	1.49	3.22	1.62	6.99
1,2-Dichlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00
1,2-Dichloroethane	0.17	0.84	0.13	1.55	0.09	0.13
1,2-Dichloropropane	0.04	0.06	0.04	0.07	0.04	0.06
1,2-Diethylbenzene	0.04	0.08	0.04	0.06	0.04	0.09
1,3,5-trimethylbenzene	0.32	0.93	0.46	0.98	0.49	2.08
1,3-Butadiene	0.19	0.73	0.36	0.77	0.34	1.03
1,3-Dichlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00
1,3-Diethylbenzene	0.07	0.16	0.08	0.16	0.09	0.27
1,4-Dichlorobenzene	0.07	0.19	0.13	0.32	0.18	0.31
1,4-Dichlorobutane	0.00	0.01	0.00	0.03	0.00	0.05
1,4-Diethylbenzene	0.19	0.45	0.23	0.43	0.23	0.76
1-Butene/Isobutene	0.88	4.24	0.98	2.17	0.92	2.68
1-Butyne	0.02	0.05	0.03	0.05	0.03	0.06
1-Decene	0.10	0.35	0.24	0.44	0.07	0.26
1-Heptene	0.49	1.76	0.28	1.04	0.23	0.82
1-Hexene	0.31	1.02	0.29	0.58	0.26	0.59
1-methylcyclohexene	0.06	0.12	0.07	0.11	0.06	0.11
1-methylcyclopentene	0.10	0.24	0.13	0.28	0.11	0.28
1-Nonene	0.06	0.25	0.06	0.13	0.07	0.31
1-Octene	0.08	0.55	0.05	0.28	0.05	0.10
1-Pentene	0.25	0.68	0.24	0.54	0.22	0.56
1-Propyne	0.14	0.58	0.23	0.50	0.21	0.72
2,2,3-Trimethylbutane	0.05	0.35	0.03	0.06	0.02	0.08
2,2,4-Trimethylpentane	1.63	5.84	1.70	4.12	1.70	6.75
2,2,5-Trimethylhexane	0.07	0.21	0.09	0.22	0.09	0.33
2,2-Dimethylbutane	0.81	5.26	0.32	0.67	0.31	0.96
2,2-Dimethylhexane	0.07	0.27	0.05	0.14	0.05	0.14
2,2-Dimethylpentane	0.22	1.60	0.13	0.27	0.12	0.34
2,2-Dimethylpropane	0.38	2.89	0.08	0.16	0.08	0.26
2,3,4-Trimethylpentane	0.39	1.35	0.51	1.24	0.52	2.04
2,3-Dimethylbutane	1.70	10.81	0.79	2.35	0.72	2.48
2,3-Dimethylpentane	1.41	4.41	1.28	3.09	1.24	4.80
2,4-Dimethylhexane	0.30	0.85	0.29	0.64	0.27	0.98
2,4-Dimethylpentane	0.84	3.25	0.64	1.68	0.62	2.35
2,5-Dimethylheptane						

Compound	Edmonton East		Edmonton Central		Calgary Central	
	Mean (µg/m^3)	Max (µg/m^3)	Mean (µg/m^3)	Max (µg/m^3)	Mean (µg/m^3)	Max (µg/m^3)
2,5-Dimethylhexane	0.23	0.72	0.20	0.46	0.19	0.71
2-ethyl-1-Butene	0.07	0.21	0.07	0.17	0.06	0.21
2-ethyltoluene	0.24	0.68	0.33	0.69	0.35	1.40
2-methyl-1-butene	0.48	3.08	0.45	1.24	0.37	1.14
2-methyl-1-Pentene						
2-methyl-2-butene	0.72	2.04	0.70	1.69	0.61	1.87
2-methyl-2-Pentene						
2-Methylheptane	0.69	2.22	0.44	1.22	0.37	1.45
2-Methylhexane	1.57	9.26	1.01	2.58	0.90	3.46
2-Methylpentane	6.75	47.42	2.76	7.78	2.42	8.95
3,6-Dimethyloctane	0.08	0.26	0.13	0.22	0.05	0.22
3-ethyltoluene	0.55	1.67	0.82	1.79	0.90	3.82
3-methyl-1-pentene	0.06	0.15	0.06	0.15	0.06	0.15
3-Methylheptane	0.45	1.46	0.38	0.93	0.34	1.32
3-Methylhexane	1.70	8.45	1.18	3.55	1.02	3.98
3-Methyloctane						
3-Methylpentane	3.78	26.96	1.73	4.28	1.48	4.97
4-ethyltoluene	0.30	0.83	0.43	0.90	0.46	1.80
4-methyl-1-pentene	0.05	0.19	0.06	0.16	0.05	0.13
4-Methylheptane	0.24	0.79	0.17	0.37	0.15	0.59
4-Methyloctane						
Acetylene	3.28	11.98	6.16	21.08	5.35	20.27
Benzene	2.03	8.29	1.83	3.88	1.75	5.04
Benzylchloride	0.05	0.09	0.05	0.10	0.05	0.10
Bromochloromethane						
Bromodichloromethane	0.13	1.09	0.11	0.20	0.10	0.16
Bromoform	0.05	0.08	0.05	0.07	0.05	0.07
Bromomethane	0.15	0.20	0.15	0.21	0.14	0.18
Bromotrichloromethane						
Butane	41.82	432.80	10.76	32.16	9.83	70.82
Carbontetrachloride	0.71	0.89	0.72	0.94	0.74	0.94
Chlorobenzene	0.00	0.03	0.00	0.00	0.00	0.00
Chloroethane	0.08	0.16	0.12	0.28	0.08	0.12
Chloroform	0.11	0.17	0.14	0.35	0.13	0.18
Chloromethane	1.16	1.60	1.19	1.85	1.19	1.57
cis-1,2-Dichloroethylene	0.04	0.08	0.04	0.06	0.03	0.05
cis-1,2-Dimethylcyclohexane	0.08	0.16	0.06	0.36	0.05	0.14
cis-1,3-Dichloropropene	0.00	0.01	0.00	0.01	0.00	0.01
cis-1,3-Dimethylcyclohexane	0.39	1.39	0.17	1.64	0.12	0.48
cis-1,4/t-1,3-Dimethylcyclohexane	0.10	0.28	0.07	0.57	0.05	0.20
cis-2-Butene	0.15	0.35	0.17	0.41	0.16	0.43
cis-2-Heptene	0.05	0.09	0.05	0.09	0.05	0.09
cis-2-Hexene	0.08	0.21	0.08	0.17	0.08	0.23
cis-2-Octene						
cis-2-Pentene	0.27	0.76	0.26	0.57	0.24	0.62

Compound	Edmonton East		Edmonton Central		Calgary Central	
	Mean (μg/m^{3})	Max (μg/m^{3})	Mean (μg/m^{3})	Max (μg/m^{3})	Mean (μg/m^{3})	Max (μg/m^{3})
cis-3-Heptene						
cis-3-methyl-2-pentene	0.11	0.31	0.11	0.24	0.10	0.29
cis-4-methyl-2-pentene	0.02	0.22	0.02	0.15	0.00	0.11
Cyclohexane	2.29	18.19	0.50	1.14	0.38	1.07
Cyclohexene	0.05	0.09	0.06	0.10	0.05	0.11
Cyclopentane	2.15	12.10	0.62	1.66	0.50	1.44
Cyclopentene	0.08	0.20	0.09	0.23	0.08	0.23
Decane	0.90	4.65	3.88	5.93	0.51	2.96
Dibromochloromethane	0.06	0.09	0.06	0.09	0.06	0.09
Dibromomethane	0.10	0.13	0.10	0.14	0.10	0.16
Dichloromethane	0.67	4.56	0.52	2.67	0.77	9.69
Dodecane	0.32	2.03	0.18	0.52	0.18	0.70
EDB	0.06	0.12	0.06	0.10	0.06	0.09
Ethane	15.11	45.28	9.65	34.42	8.13	24.83
Ethylbenzene	0.98	4.08	1.27	2.89	1.31	6.83
Ethylbromide	0.03	0.10	0.03	0.06	0.03	0.05
ethylene	5.52	28.70	5.13	11.74	4.61	15.87
Freon11	1.82	2.39	1.87	2.78	2.03	4.25
Freon113	1.74	4.57	0.79	1.15	0.71	0.97
Freon114	0.23	0.31	0.25	0.59	0.23	0.29
Freon12	2.77	3.88	2.87	3.60	2.97	4.29
Freon22	0.76	6.61	0.92	3.97	1.01	6.95
Heptane	2.30	12.87	1.07	3.09	0.86	3.28
Hexachlorobutadiene	0.00	0.00	0.00	0.00	0.00	0.00
Hexane	6.32	50.92	1.78	3.76	1.55	4.65
Hexylbenzene	0.12	0.82	0.12	0.78	0.14	0.92
Indane	0.12	0.29	0.16	0.32	0.17	0.53
Isobutane	16.45	149.64	4.03	13.74	3.69	36.17
iso-butylbenzene	0.04	0.08	0.04	0.07	0.04	0.09
Isopentane	27.65	206.22	6.94	15.04	6.19	18.81
Isoprene	0.54	4.08	0.55	2.78	0.38	1.78
iso-Propylbenzene	0.09	0.20	0.09	0.18	0.09	0.29
m and p-Xylene	3.32	14.37	4.42	10.11	4.80	25.45
methylcyclohexane	2.54	15.93	0.67	1.60	0.53	2.19
methylcyclopentane	3.31	20.76	1.36	2.99	1.10	3.19
Naphthalene						
n-butylbenzene	0.07	0.15	0.07	0.14	0.07	0.22
Nonane	0.89	3.01	0.40	0.91	0.33	1.72
n-Propylbenzene	0.20	0.51	0.24	0.52	0.24	0.90
Octane	0.91	2.88	0.46	1.97	0.37	1.44
o-Xylene	1.15	4.82	1.55	3.52	1.70	8.45
p-Cymene	0.17	0.68	0.14	0.36	0.14	0.50
Pentane	21.18	174.17	3.81	8.62	3.05	8.53
Propane	37.64	195.85	11.45	34.20	8.34	26.48
Propylene	1.09	5.07	1.82	3.84	1.72	5.90
sec-butylbenzene	0.05	0.12	0.05	0.24	0.05	0.39

Compound	Edmonton East		Edmonton Central		Calgary Central	
	Mean (μg/m^3)	Max (μg/m^3)	Mean (μg/m^3)	Max (μg/m^3)	Mean (μg/m^3)	Max (μg/m^3)
Styrene	0.92	9.82	0.25	0.88	0.27	1.22
tert-butylbenzene	0.01	0.09	0.02	0.06	0.02	0.06
Tetrachloroethylene	0.36	1.49	0.51	1.50	0.76	2.61
toluene	4.54	30.20	5.21	26.59	5.38	23.74
trans-1,2-Dichloroethylene	0.03	0.05	0.03	0.05	0.03	0.05
trans-1,2-Dimethylcyclohexane	0.30	0.99	0.12	1.09	0.09	0.36
trans-1,3-Dichloropropene	0.01	0.03	0.01	0.03	0.01	0.03
trans-1,4-Dimethylcyclohexane	0.18	0.67	0.08	0.61	0.06	0.23
trans-2-Butene	0.15	0.42	0.18	0.46	0.17	0.65
trans-2-Heptene	0.04	0.09	0.05	0.10	0.05	0.10
trans-2-Hexene	0.09	0.25	0.10	0.24	0.09	0.29
trans-2-Octene						
trans-2-Pentene	0.37	1.15	0.35	0.89	0.31	0.95
trans-3-Heptene	0.01	0.04	0.02	0.04	0.01	0.04
trans-3-methyl-2-pentene	0.09	0.29	0.10	0.25	0.09	0.25
trans-4-methyl-2-pentene	0.00	0.03	0.00	0.04	0.00	0.03
Trichloroethylene	0.31	3.94	0.13	0.72	0.16	0.71
Undecane	0.54	2.22	0.66	1.29	0.37	2.00
Vinylchloride	0.03	0.10	0.03	0.10	0.02	0.04

Table A3-4 Average ambient VOC concentrations at Wood Buffalo Environmental Association monitoring stations in 1999 and 2000

Compound	Athabasca Valley		Patricia McInnes		Fort McKay		Barge Landing
	1999 (ppbv)	2000 (ppbv)	1999 (ppbv)	2000 (ppbv)	1999 (ppbv)	2000 (ppbv)	2000 (ppbv)
1,2,4-Trimethylbenzene	0.49	0.57	0.33	0.28	0.23	0.13	0.09
1,3,5-Trimethylbenzene	0.21	0.16	0.28	0.26	0.23	0.06	0.06
1-Butene	0.39	0.38	0.34	0.19	0.28	0.27	0.16
1-Pentene	0.13	0.06	0.08	-*	0.08	0.08	-
2,2,4-Trimethylpentane	0.20	0.25	0.17	0.21	0.07	0.16	1.25
2,2-Dimethylbutane	0.11	0.10	0.12	0.09	0.10	0.11	0.05
2,3 -Dimethylbutane	0.15	0.15	0.16	0.18	0.21	0.18	0.10
2,3,4-Trimethylpentane	0.16	0.11	0.21	0.08	0.27	0.08	0.29
2,3-Dimethylpentane	0.30	0.40	0.31	0.21	0.24	0.30	-
2,4 -Dimethylpentane	0.21	0.13	0.12	0.11	0.25	0.08	-
2-Methyl-1-Pentene	0.11	0.12	0.09	0.12	0.33	0.21	0.35
2-Methyl-2-Butene	0.16	0.11	0.16	0.10	0.07	0.07	-
2-Methylheptane	0.50	0.24	0.20	0.13	0.41	0.52	0.30
2-Methylhexane	0.24	0.18	0.30	0.15	0.21	0.21	-
2-Methylpentane	0.58	0.60	0.75	0.56	0.56	0.42	-
3-Methyl-1-Butene	0.11	0.05	0.05	-	0.06	-	-
3-Methylheptane	0.27	0.28	0.18	0.11	0.39	0.30	-
3-Methylhexane	0.27	0.16	0.17	0.14	0.20	0.24	0.13
3-Methylpentane	0.26	0.24	0.29	0.15	0.30	0.20	0.11
4-Methyl-1-Pentene	0.27	-	-	-	0.25	-	-
Alpha-Pinene	0.60	-	-	-	-	-	0.76
Benzene	0.96	0.33	0.77	0.25	0.86	0.24	0.13
β-Pinene	0.58	2.68	0.58	-	-	0.43	0.97
Butane	2.92	2.22	1.75	0.90	3.93	1.32	0.56
cis-2-Butene	0.15	0.09	0.09	0.09	0.11	0.10	-
cis-2-Hexene	0.08	-	-	-	0.07	-	-
cis-2-Pentene	0.15	-	0.12	-	0.12	-	-
Cyclohexane	0.14	0.11	0.09	0.13	0.23	0.19	0.13
Cyclopentane	0.29	0.19	0.45	0.19	0.28	0.21	-
Cyclopentene	-	0.01	0.63	-	0.13	-	-
Ethylbenzene	0.25	0.16	0.17	0.11	0.12	0.17	0.09
Heptane	0.21	0.16	0.17	0.13	0.43	0.47	0.29
Hexane	0.70	0.27	0.63	0.24	0.74	0.41	0.23
Isobutane	1.50	0.98	1.11	0.67	1.41	0.65	0.45
Isopentane	2.99	1.44	3.05	0.88	2.59	0.85	0.19
Isoprene	0.34	1.15	0.34	1.14	0.42	0.47	-
Isopropylbenzene	0.12	0.03	0.04	-	0.09	0.07	-
m/p-Xylene	0.77	0.49	0.54	0.32	0.30	0.41	0.24
Methylcyclohexane	0.09	0.12	0.09	0.10	0.23	0.27	0.18
Methylcyclopentane	0.24	0.19	0.26	0.19	0.41	0.22	0.17
Nonane	0.29	0.18	0.08	0.05	0.21	0.20	0.12

Compound	Athabasca Valley		Patricia McInnes		Fort McKay		Barge Landing
	1999 (ppbv)	2000 (ppbv)	1999 (ppbv)	2000 (ppbv)	1999 (ppbv)	2000 (ppbv)	2000 (ppbv)
n-Propylbenzene	0.16	0.06	0.17	0.04	0.14	0.10	0.03
Octane	1.44	0.40	0.12	0.12	0.55	0.49	0.28
o-Xylene	0.43	0.25	0.28	0.14	0.15	0.16	0.11
Pentane	0.69	0.55	0.45	0.38	0.68	0.51	0.27
Styrene	0.09	0.11	0.23	0.56	0.12	-	-
Toluene	0.84	1.02	0.50	0.33	0.62	0.37	3.35
Trans 2-Hexene	0.16	-	0.19	0.06	0.41	0.10	0.14
Trans-2-Butene	0.17	0.23	0.19	-	0.20	0.21	-
Trans-2-Pentene	0.17	0.09	0.12	0.08	0.08	-	-
* No Data							

Table A3-5 Ambient BTEX concentrations measured at Violet Grove in 2000

Compound	2/15/00	3/29/00	6/28/00	8/30/00	9/27/00	11/15/00	12/21/00	Annual Average
Benzene (ppbv)	0.24	1.44	0.01	1.22	0.16	0.14	0.41	0.52
Toluene (ppbv)	0.45	2.49	0.1	15.74	2.30	0.58	4.08	3.68
Ethyl benzene (ppbv)	0.04	0.635	0.01	0.61	0.12	0.05	0.10	0.22
m/p-xylene (ppbv)	0.1	0.61	0.04	2.08	0.34	0.10	0.40	0.52
o-xylene (ppbv)	0.03	0.14	-*	0.66	0.11	0.03	0.10	0.18
* No Data								

Table A3-6 Average total hydrocarbon concentrations measured in the Parkland Airshed Management Zone

Month	Stationary	Portable				
	Caroline	Alix	Crossfield	Leslieville	Rimbey	Sundre
August, 2000	2.24	-*	-	-	-	-
September, 2000	2.35	-	-	-	-	-
October, 2000	2.29	2.01	-	-	-	-
November, 2000	2.17	1.97	1.88	-	-	-
December, 2000	2.24	-	1.91	-	2.79	-
January, 2001	2.09	-	-	-	2.61	2.10
February, 2001	2.10	-	2.12	-	-	2.02
March, 2001	2.02	-	2.01	2.01	-	-
April, 2001	1.97	2.03	-	2.01	-	-
May, 2001	1.99	2.01	1.96	-	-	-
June, 2001	1.90	-	-	-	-	-
July, 2001	1.82	-	-	-	-	-
August, 2001	1.87	-	-	-	-	2.10
September, 2001	2.15	-	2.03	2.11	-	-
* The portable air monitoring stations are not continuously operational; this accounts for the lack of data during some months.						

Appendix 4: Sources of VOC in Indoor Environments

Table A4-1 VOCs that may be emitted from building materials and their potential sources (California Department of Health Services 1996)

Chemical Name	Potential Sources
Acetic acid	Solvent for resins, caulks, sealants, glazing compounds, volatile oils
Acetone (2-Propanone)	Lacquer solvent
1-Amyl alcohol (Amyl alcohol; Pentyl alcohol; 1-Pentanol)	Solvent in organic synthesis
Benzaldehyde	Fiberboard, particleboard
Benzene	Adhesives, spot cleaners, alkyd paints, paint removers, particleboard, furniture waxes
2-Butanone (Methyl ethyl ketone)	Floor/wall coverings, fiberboard, caulking compounds, particleboard
n-Butyl acetate (Butyl acetate)	Floor lacquers
Butyl acrylate (Butyl-2-propenoate)	Used in manufacture of polymers and resins for textile and leather finishes
n-Butyl alcohol (1-Butanol)	Edge sealings, molding tapes, jointing compounds, cement flagstones, linoleum floor coverings, floor lacquers, industrial cleaners, paint removers
n-Butylbenzene	Solvent
Camphene	Occurs in many essential oils
Chlorobenzene	Solvent for paint, used in manufacture of phenol
Cyclohexane	Solvent for lacquers and resins, paint and varnish removers
Cyclohexanone	Solvent for many resins and waxes
Dibutylphthalate (Di-n-butyl phthalate)	Plasticizer
Diethylamine	Used in resins, dyes, and in manufacture of rubber
Dimethyl acetamide (N,N-Dimethyl acetamide)	Solvent for organic reactions
Dioxane (p-Dioxane; 1,4-Dioxane)	Solvent for many oils, waxes, dyes, cellulose acetate
Dodecane (n-Dodecane)	Floor varnishes, floor/wall coverings
2-Ethoxyethanol (Cellosolve®; Ethylene glycol monoethyl ether)	Epoxy paints, latex paints, polyurethane varnishes
2-Ethoxyethyl acetate (Cellosolve® acetate; Ethylene glycol monoethyl ether acetate)	Floor lacquers, epoxy paints
Ethyl acetate	Vinyl floor coverings, solvent for varnishes and lacquers
Ethyl alcohol (Ethanol)	Fiberboard, solvents
Ethyl benzene	Floor/wall coverings, insulation foam, chipboard, caulking compounds, jointing compounds, fiberboard, adhesives, floor lacquers, grease cleaners
2-Ethyltoluene (o-Ethyltoluene)	Floor waxes
Formaldehyde (Methanal)	**Major Sources:** MDF, plywood, particleboard, ceiling panels, fiberboard, chipboard **Minor Sources:** Upholstery fabrics, latex-backed fabrics, fiberglass, fiberglass insulation in air ducts, urea formaldehyde foam insulation, wallpaper, caulking compounds, jointing compounds, floor and furniture varnishes, adhesives, floor lacquers, gypsum board
Heptane (n-Heptane)	Floor coverings, floor varnishes
Hexachlorobenzene	Fungicide
Hexanal	Polyurethane wood finish
Hexane (n-Hexane)	Chipboard, gypsum board, insulation board, floor coverings, wallpaper

Chemical Name	Potential Sources
Isobutyl acetate (2-Methylpropyl acetate)	Floor lacquers
Isobutyl alcohol (Isobutanol; 2-Methyl-1-propanol)	Edge sealings, molding tapes, jointing compounds, cement flagstone, linoleum floor coverings, floor lacquers
Isopropyl alcohol (Isopropanol; 2-Propanol)	Particleboard
Isoquinolone	Used in synthesis of dyes and insecticides; rubber accelerator
d-Limonene	Paints, adhesives, chipboard, detergents, furniture polish
Methylene chloride (Methane dichloride; Dichloromethane)	Paint removers, aerosol paints, industrial solvents
Methyl isobutyl ketone (MIBK; 4-Methyl-2-pentanone)	Floor/wall coverings
2-Methylpentane (Isohexane)	Chipboard, gypsum board, insulation foam, floor coverings, wallpaper
Nonane (n-Nonane)	Wallpaper, caulking compounds, floor coverings, chipboard, adhesives, cement flagstone, jointing compounds, floor varnishes, floor waxes
Nonyl phenol isomers	Used in manufacture of lubricating oil additives, resins, plasticizers, and surface active agents
Pentachlorophenol (PCP)	Wood preservative, disinfectant, fungicide, paints, wallpaper, adhesives, textiles, wood finishes, floor shampoos
4-Phenylcyclohexene (4-PC; Cyclohexylbenzene)	Manufacturing by-product in carpets with SBR latex backing
α-Pinene	Cement flagstone, fiberboard, gypsum board, adhesives, insulation sheets, chipboard, wood
n-Propyl acetate	Plastics
Propylbenzenes (n-Propyl benzene)	Adhesives, floor/wall coverings, chipboard, paints, caulking compounds, insulation foam
Quinolone	Used in the manufacture of dyes; solvent for resins
Styrene (Vinyl benzene)	Insulation foam, jointing compounds, fiberboard, carpets with SBR latex backing
α-Terpinene (1-Methyl-4-isopropyl-1,3-cyclohexadiene)	Furniture polishes
Tetrachloroethylene (Perchloroethylene)	Widely used in the textile industry for dry cleaning, processing, and finishing of fabrics; used in metal degreasers, spot removers, adhesives, wood cleaners, and lubricants
Tetrachlorophenol	Wood preservative
Toluene	Solvent-based adhesives, water-based adhesives, edge sealings, molding tapes, wallpaper, jointing compounds, floor coverings, vinyl coated wallpaper, caulking compounds, paints, chipboard, vinyl floor coverings
1,1,1-Trichloroethane (Methyl chloroform)	Cleaning fluids, water and stain repellents
Trichloroethylene (TCE)	Solvent for paints and varnishes
1,2,3-Trimethylbenzene	Floor/wall coverings, floor waxes
1,2,4-Trimethylbenzene	Floor/wall coverings, linoleum floor coverings, caulking compounds, vinyl coated wallpaper, jointing compounds, cement flagstone, floor varnishes, chipboard, floor waxes
1,3,5-Trimethylbenzene (Mesitylene)	Caulking compounds, floor/wall coverings, floor waxes
Undecane (n-Undecane)	Wallpaper, gypsum board, floor/wall coverings, joint compounds, chipboard, floor varnishes, paints, paint removers
Xylenes	Adhesives, jointing compounds, wallpaper, caulking compounds, floor coverings, floor lacquers, grease cleaners, varnishes

Appendix 5: Human Health Effects of VOC Exposure

Table A5-1 Organic compounds considered to be human carcinogens by the United States Department of Health and Human Services (DHHS 2001)

CAS	Name or Synonym
1402-68-2	Aflatoxins
92-67-1	4-Aminobiphenyl (4-Aminodiphenyl)
91-59-8	2-Aminonaphthalene
446-86-6	Azathioprine
71-43-2	Benzene
92-87-5	Benzidine
542-88-1	bis(Chloromethyl) Ether
106-99-0	1,3-Butadiene
55-98-1	1,4-Butanediol Dimethylsulfonate (Myleran®; Busulfan)
305-03-3	Chlorambucil
13909-09-6	1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea (MeCCNU)
107-30-2	Chloromethyl Methyl Ether
8007-45-2	Coal Tar (under Tars and Mineral Oils)
8001-58-9	Creosote (Coal) (under Tars and Mineral Oils)
8021-39-4	Creosote (Wood) (under Tars and Mineral Oils)
50-18-0	Cyclophosphamide
59865-13-3	Cyclosporin A (Cyclosporine A; Ciclosporin)
56-53-1	Diethylstilbestrol
75-21-8	Ethylene Oxide
148-82-3	Melphalan
298-81-7	Methoxsalen (under Methoxsalen with Ultraviolet A Therapy (PUVA)) (methoxsalen not carcinogenic alone)
7280-37-7	Piperazine Estrone Sulfate (under Conjugated Estrogens)
7789-06-2	Strontium Chromate (under Chromium Hexavalent Compounds)
10540-29-1	Tamoxifen
52-24-4	Thiotepa [in 7th ARC as tris(1-Aziridinyl)phosphine Sulfide]
52-24-4	Tris(1-aziridinyl)phosphine Sulfide (Thiotepa)
75-01-4	Vinyl Chloride

Table A5-2 Organic compounds anticipated to be human carcinogens by the United States Department of Health and Human Services (DHHS 2001)

CAS	NAME OR SYNONYM
75-07-0	Acetaldehyde
53-96-3	2-Acetylaminofluorene
79-06-1	Acrylamide
107-13-1	Acrylonitrile
25316-40-9	Adriamycin® (Doxorubicin hydrochloride)
117-79-3	2-Aminoanthraquinone
97-56-3	*o*-Aminoazotoluene
82-28-0	1-Amino-2-methylanthraquinone
61-82-5	Amitrole
134-29-2	*o*-Anisidine Hydrochloride
	Aroclor (under Polychlorinated Biphenyls)
11097-69-1	Aroclor® 1254 (under Polychlorinated Biphenyls)
11096-82-5	Aroclor® 1260 (under Polychlorinated Biphenyls)
320-67-2	Azacitidine (5-Azacytidine)
56-55-3	Benz[*a*]anthracene (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
205-99-2	Benzo[*b*]fluoranthene (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
205-82-3	Benzo[*j*]fluoranthene (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
207-08-9	Benzo[*k*]fluoranthene (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
50-32-8	Benzo[*a*]pyrene (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
98-07-7	Benzotrichloride
154-93-8	bis(Chloroethyl) Nitrosourea (BCNU)
90-94-8	bis(Dimethylamino)benzophenone (Michler's Ketone)
117-81-7	bis(2-Ethylhexyl) Phthalate (di(2-Ethylhexyl) phthalate)
75-27-4	Bromodichloromethane
25013-16-5	Butylated Hydroxyanisole (BHA)
56-23-5	Carbon Tetrachloride
143-50-0	Chlordecone (see Kepone®)
115-28-6	Chlorendic Acid
108171-26-2	Chlorinated Paraffins (C12, 60% Chlorine)
13010-47-4	1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea (CCNU)
67-66-3	Chloroform
563-47-3	3-Chloro-2-methylpropene
95-83-0	4-Chloro-*o*-phenylenediamine
126-99-8	Chloroprene
95-69-2	*p*-Chloro-*o*-toluidine
3165-93-3	*p*-Chloro-*o*-toluidine Hydrochloride
54749-90-5	Chlorozotocin
120-71-8	*p*-Cresidine
135-20-6	Cupferron
4342-03-4	Dacarbazine
117-10-2	2Danthron (1,8-Dihydroxyanthraquinone)
50-29-3	DDT (Dichlorodiphenyltrichloroethane)
13654-09-6	Decabromobiphenyl (Under Polybrominated Biphenyls)
117-81-7	DEHP [See di(2-Ethylhexyl) Phthalate]
55-18-5	DEN (See *N*-Nitrosodiethylamine)
39156-41-7	2,4-Diaminoanisole Sulfate
101-80-4	Diaminodiphenyl Ether (See 4,4′-Oxydianiline)

CAS	NAME OR SYNONYM
95-80-7	2,4-Diaminotoluene
226-36-8	Dibenz[*a,h*]acridine (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
224-42-0	Dibenz[*a,j*]acridine (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
53-70-3	Dibenz[*a,h*]anthracene (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
194-59-27	*H*-Dibenzo[*c,g*]carbazole (under Polycyclic Aromatic Hydrocarbons)
192-65-4	Dibenzo[*a,e*]pyrene (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
189-64-0	Dibenzo[*a,h*]pyrene (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
189-55-9	Dibenzo[*a,i*]pyrene (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
191-30-0	Dibenzo[*a,l*]pyrene (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
96-12-8	1,2-Dibromo-3-chloropropane
106-93-4	1,2-Dibromoethane (Ethylene dibromide; EDB)
106-46-7	1,4-Dichlorobenzene (*p*-Dichlorobenzene)
91-94-1	3,3′-Dichlorobenzidine
612-83-9	3,3′-Dichlorobenzidine Dihydrochloride
50-29-3	Dichlorodiphenyltrichloroethane (See DDT)
107-06-21,2	1,2-Dichloroethane (Ethylene Dichloride)
75-09-2	Dichloromethane (Methylene Chloride)
542-75-6	1,3-Dichloropropene (Technical Grade)
1464-53-5	Diepoxybutane
95-06-7	*N,N*-Diethyldithiocarbamic Acid 2-Chloroallyl Ester (See Sulfallate)
55-18-5	Diethylnitrosamine (*N*-Nitrosodiethylamine)
64-67-5	Diethyl Sulfate
101-90-6	Diglycidyl Resorcinol Ether
117-10-21,8-	1,8-Dihydroxyanthraquinone [See Danthron]
119-90-4	3,3′-Dimethoxybenzidine
60-11-7	4-Dimethylaminoazobenzene
119-93-7	3,3′-Dimethylbenzidine
79-44-7	Dimethylcarbamoyl Chloride
57-14-7	1,1-Dimethylhydrazine (UDMH)
62-75-9	Dimethylnitrosamine (*N*-Nitrosodimethylamine)
77-78-1	Dimethyl Sulfate
513-37-1	Dimethylvinyl Chloride
42397-64-8	1,6-Dinitropyrene
42397-65-9	1,8-Dinitropyrene
123-91-1	1,4-Dioxane
25316-40-9	Doxorubicin hydrochloride (Adriamycin®)
106-89-8	Epichlorohydrin
50-28-2	Estradiol-17β(under Estrogens [Not Conjugated])
53-16-7	Estrone (under Estrogens [Not Conjugated])
57-63-6	Ethinylestradiol (under Estrogens [Not Conjugated])
51-79-6	Ethyl Carbamate (Urethane)
96-45-7	Ethylene Thiourea
62-50-0	Ethyl Methanesulfonate
759-73-9	*N*-Ethyl-*N*-nitrosourea (*N*-Nitroso-*N*-ethylurea)
50-00-0	Formaldehyde (gas)
110-00-9	Furan
556-52-5	Glycidol
67774-32-7	Hexabromobiphenyl (FireMaster FF-1, Under Polybrominated Biphenyls)
118-74-1	Hexachlorobenzene
319-84-6	α-Hexachlorocyclohexane (under Lindane and Other Hexachlorocyclohexane
319-85-7	β-Hexachlorocyclohexane (under Lindane and Other Hexachlorocyclohexane

CAS	NAME OR SYNONYM
58-89-9	γ-Hexachlorocyclohexane (under Lindane and Other Hexachlorocyclohexane
608-73-1	Hexachlorocyclohexane (under Lindane and Other Hexachlorocyclohexane
67-72-1	Hexachloroethane
680-31-9	Hexamethylphosphoramide
302-01-2	Hydrazine
10034-93-2	Hydrazine Sulfate
122-66-7	Hydrazobenzene
193-39-5	Indeno[1,2,3-*cd*]pyrene (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
9004-66-4	Iron Dextran Complex
78-79-5	Isoprene
37317-41-2	Kanechlor ® 500 (under Polychlorinated Biphenyls)
143-50-0	Kepone® (Chlordecone)
58-89-9	Lindane (under Lindane and Other Hexachlorocyclohexane Isomers)
72-33-3	Mestranol (under Estrogens [Not Conjugated])
3697-24-3	5-Methylchrysene (under Polycyclic Aromatic Hydrocarbons, 15 Listings)
101-14-4	4,4'-Methylenebis(2-chloraniline) (MBOCA)
101-61-1	4,4'-Methylenebis(*N,N*-dimethylbenzenamine)
101-77-9	4,4'-Methylenedianiline
13552-44-8	4,4'-Methylenedianiline Dihydrochloride
66-27-3	Methyl Methanesulfonate
70-25-7	*N*-Methyl-*N'*-nitro-*N*-nitrosoguanidine
684-93-5	*N*-Methyl-*N*-nitrosourea (*N*-Nitroso-*N*-methylurea)
443-48-1	Metronidazole
2385-85-5	Mirex
139-13-9	Nitrilotriacetic Acid
91-23-6	*o*-Nitroanisole
7496-02-8	6-Nitrochrysene
1836-75-5	Nitrofen
55-86-7	Nitrogen Mustard Hydrochloride
79-46-9	2-Nitropropane
5522-43-0	1-Nitropyrene
57835-92-4	4-Nitropyrene
38252-74-3	*N*-Nitroso-*n*-butyl-*N*-(3-carboxypropyl)amine (under *N*-Nitrosodi-*n*-butylamine)
3817-11-6	*N*-Nitroso-*n*-butyl-*N*-(4-hydroxybutyl)amine (under *N*-Nitrosodi-*n*-butylamine)
924-16-3	*N*-Nitrosodi-*n*-butylamine
1116-54-7	*N*-Nitrosodiethanolamine
55-18-5	*N*-Nitrosodiethylamine (Diethylnitrosamine; DEN)
621-64-7	*N*-Nitrosodi-*n*-propylamine
759-73-9	*N*-Nitroso-*N*-ethylurea (*N*-Ethyl-*N*-nitrosourea; ENU)
64091-91-4	4-(*N*-Nitrosomethylamino)-1-(3-pyridyl)-1-butanone (NNK)
684-93-5	*N*-Nitroso-*N*-methylurea (*N*-Methyl-*N*-nitrosourea)
4549-40-0	*N*-Nitrosomethylvinylamine
59-89-2	*N*-Nitrosomorpholine
16543-55-8	*N*-Nitrosonornicotine
100-75-4	*N*-Nitrosopiperidine
930-55-2	*N*-Nitrosopyrrolidine
13256-22-9	*N*-Nitrososarcosine
68-22-4	Norethisterone
303-47-9	Ochratoxin A
61288-13-9	Octabromobiphenyl (Under Polybrominated Biphenyls)
101-80-4	4,4'-Oxydianiline

CAS	NAME OR SYNONYM
434-07-1	Oxymetholone
62-44-2	Phenacetin (See also Analgesic Mixtures Containing Phenacetin)
136-40-3	Phenazopyridine Hydrochloride
77-09-8	Phenolphthalein
63-92-3	Phenoxybenzamine Hydrochloride
57-41-0	Phenytoin
	Polybrominated Biphenyls (PBBs)
1336-36-3	Polychlorinated Biphenyls (PCBs)
	Polycyclic Aromatic Hydrocarbons (PAHs)
366-70-1	Procarbazine Hydrochloride
57-83-0	Progesterone
1120-71-4	1,3-Propane Sultone
57-57-8	β-Propiolactone
75-56-9	Propylene Oxide
75-55-8	Propylenimine (2-Methylaziridine)
51-52-5	Propylthiouracil
50-55-5	Reserpine
94-59-7	Safrole
18883-66-4	Streptozotocin
95-06-7	Sulfallate
1746-01-6	2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD)
127-18-4	Tetrachloroethylene (Perchloroethylene)
116-14-3	Tetrafluoroethylene
509-14-8	Tetranitromethane
62-55-5	Thioacetamide
62-56-6	Thiourea
26471-62-5	Toluene Diisocyanate
95-53-4	*o*-Toluidine
636-21-5	*o*-Toluidine Hydrochloride
8001-35-2	Toxaphene
79-01-6	Trichloroethylene
88-06-22	2,4,6-Trichlorophenol
96-18-4	1,2,3-Trichloropropane
126-72-7	tris(2,3-Dibromopropyl) Phosphate
106-87-6	4-Vinyl-1-cyclohexene Diepoxide

Table A5-3 Estimated nationwide annual cancer cases caused by atmospheric pollutants in the USA (EPA 1990)

Pollutant	EPA Classification[1]	Estimated Annual Cancer Cases
Acrylonitrile	B1	13
Arsenic	A	68
Asbestos	A	88
Benzene	A	181
1,3-Butadiene	B2	266
Cadmium	B1	10
Carbon tetrachloride	B2	41
Chloroform	B2	115
Chromium (hexavalent)	A	147 - 265
Coke oven emissions	A	7
Dioxin	B2	2 - 125
Ethylene dibromide	B2	68
Ethylene dichloride	B2	45
Ethylene oxide	B1-B2	6
Formaldehyde	B1	124
Gasoline vapours	B2	19 - 76
Hexachlorobutadiene	C	9
Hydrazine	B2	6
Methylene chloride	B2	5
Perchloroethylene	B2	6
Products of incomplete combustion (PICs)	-	438 - 1120
Radionuclides	A	3
Radon	A	2
Trichloroethylene	B2	7
Vinyl chloride	A	25
Vinylidene chloride	C	10
Miscellaneous	-	15
Total		1,726 - 2,706

[1] The EPA classifications used are: A = proven human carcinogen; B = probable human carcinogen (B1 indicates limited evidence from human studies and sufficient evidence from animal studies; B2 indicates sufficient evidence from animal studies, but inadequate evidence from human studies); C = possible human carcinogen.

Table A5-4 Unit risk factors for various substances, as determined by the US Environmental Protection Agency (EPA 1990)

Contaminant Name	EPA Classification[3]	Unit Risk Factors $(\mu g/m^3)^{-1}$
Acetaldehyde	B2	$2.2x10^{-6}$
Acrylamide	B2	$1.1x10^{-3}$
Acrylonitrile	B1	$6.8x10^{-5}$
Aldrin	B2	$4.9x10^{-3}$
Allyl chloride	B2	$5.5x10^{-8}$
Aniline	B2	$7.4x10^{-6}$
Arsenic	A	$4.3x10^{-3}$
Asbestos	A	$7.6x10^{-3}$
Benz(a)anthracene	B2	$8.9x10^{-4}$
Benzene	A	$8.3x10^{-6}$
Benzidine	A	$6.7x10^{-2}$
Beryllium	B2	$2.4x10^{-3}$
Bis(2-chloroethyl)ether	B2	$3.3x10^{-4}$
Bis(chloromethyl)ether	A	$2.7x10^{-3}$
Bis(2-ethylhexyl)phthalate	B2	$2.4x10^{-7}$
1,3-Butadiene	B2	$2.8x10^{-4}$
Cadmium	B1	$1.8x10^{-3}$
Carbon Tetrachloride	B2	$1.5x10^{-5}$
Chlordane	B2	$3.7x10^{-4}$
Chloroform	B2	$2.3x10^{-5}$
Chloromethane	--	$3.6x10^{-6}$
Chromium (hexavalent)	A	$1.2x10^{-2}$
Coke Oven Emissions	A	$6.2x10^{-4}$
DDT	B2	$3.0x10^{-4}$
Dibenz(a,h)anthracene	B2	$1.4x10^{-2}$
1,2-Dibromo-3-chloropropane	B2	$6.3x10^{-3}$
1,2-Dichloropropane	C	$1.8x10^{-5}$
Dieldrin	B2	$4.6x10^{-3}$
Diethylstilbesterol	--	$1.4x10^{-1}$
Dimethylnitrosamine		$1.4x10^{-2}$
2,4-Dinitrotoluene	B2	$8.8x10^{-5}$
1,4-Dioxane	B2	$1.4x10^{-6}$
Dioxin	B2	$3.3x10^{1}$
1,2-Diphenylhydrazine	B2	$2.2x10^{-4}$
Epichlorohydrin	B2	$1.2x10^{-6}$
Ethylene dibromide	B2	$2.2x10^{-4}$
Ethylene dichloride	B2	$2.6x10^{-5}$
Ethylene oxide	B1-B2	$1.0x10^{-4}$
Formaldehyde	B1	$1.3x10^{-5}$
Gasoline Vapours	B2	$6.6x10^{-7}$
Heptachlor	B2	$1.3x10^{-3}$
Heptachlor epoxide	B2	$2.6x10^{-3}$
Hexachlorobenzene	B2	$4.9x10^{-4}$
Hexachlorobutadiene	C	$2.2x10^{-5}$
gamma-Hexachlorocyclohexane	C	$3.8x10^{-4}$

Contaminant Name	EPA Classification[3]	Unit Risk Factors $(\mu g/m^3)^{-1}$
Hexachloroethane	C	4.0×10^{-6}
Hydrazine	B2	2.9×10^{-3}
methyl chloride	C	3.6×10^{-6}
3-Methylchloanthrene	B2	2.7×10^{-3}
Methyl hydrazine	B2	3.1×10^{-4}
Methylene chloride	B2	4.7×10^{-7}
Nickel (subsulfide)	A	4.8×10^{-4}
2-Nitropropane	B2	2.7×10^{-3}
n-Nitrosodi-n-butylamine	B2	1.6×10^{-3}
n-Nitrosodiethylamine	B2	4.3×10^{-2}
n-Nitroso-n-methylurea	B2	8.6×10^{-2}
n-Nitrosopyrrolidine	B2	6.1×10^{-4}
Pentachloronitrobenzene	C	7.3×10^{-5}
Perchloroethylene	B2	5.8×10^{-7}
PCBs	B2	1.2×10^{-3}
Pronamide	C	4.6×10^{-6}
Propylene oxide	B2	3.7×10^{-6}
Reserpine	B2	3.0×10^{-3}
Styrene	B2	5.7×10^{-7}
1,1,2,2-Tetrachloroethane	C	5.8×10^{-5}
Thiourea	B2	5.5×10^{-4}
Toxaphene	B2	3.2×10^{-3}
1,1,2-Trichloroethane	C	1.6×10^{-5}
Trichloroethylene	B2	1.7×10^{-6}
2,4,6-Trichlorophenol	B2	5.7×10^{-6}
Vinyl chloride	A	4.1×10^{-6}
Vinylidine chloride	C	5.0×10^{-5}

[3] The EPA classifications used are: A = proven human carcinogen; B = probable human carcinogen (B1 indicates limited evidence from human studies and sufficient evidence from animal studies; B2 indicates sufficient evidence from animal studies, but inadequate evidence from human studies); C = possible human carcinogen

Table A5-5 Health Canada Tolerable Daily Intakes, Tolerable Concentrations, Tumorigenic Doses and Tumorigenic Concentrations determined by Health Canada (1996)

Substance	Classification of Carcinogenicity in CEPA Assessment[5]	Tolerable Daily Intake (Oral)[6]	Tolerable Concentration (Inhalation)	Tumorigenic Dose (ingestion)	Tumorigenic Concentration (inhalation)
Aniline	Group III	7 µg/kg b.w./day			
Benzene	Group I				15 mg/m^3
Bis (2-ethyl-hexyl) phthalate	Group IV	0.044 mg/kg b.w./day			
Bis (chloromethyl) ether	Group I				5.3 ug/m^3
Chlorinated paraffins:					
Short Chain (<C13)	Group II	0.01 mg/kg b.w./day			
Medium Chain (C14-17)	Group VI	0.006 mg/kg b.w./day			
Long Chain (>C18)	Group III	0.071 mg/kg b.w./day			
Chlorobenzene	Group III	0.43 mg/kg b.w./day	0.01 mg/m^3		
Dibutyl phthalate	Group IV	0.063 mg/kg b.w./day			
1,2-Dichlorobenzene	Group V	0.43 mg/kg b.w./day			
1,4-Dichlorobenzene	Group III	0.11 mg/kg b.w./day	0.095 mg/m^3		
3,3-Dichlorobenzidine	Group II			0.74 mg/kg b.w./day	
1,2-Dichloroethane	Group II			6.2 mg/kg b.w./day	
Dichloromethane	Group II	0.05 mg/kg b.w./day			2200 mg/m^3
Hexachlorobenzene	Group II	500 ng/kg b.w./day	0.052 mg/m^3	0.06 mg/kg b.w./day	
Methyl methacrylate	Group IV	0.05 mg/kg b.w./day	0.037 mg/m^3		
Methyl tertiary-butyl ether	Group IV	0.01 mg/kg b.w./day			
Pentachlorobenzene	Group IV	1 ug/kg b.w./day			

Substance	Classification of Carcinogenicity in CEPA Assessment[5]	Tolerable Daily Intake (Oral)[6]	Tolerable Concentration (Inhalation)	Tumorigenic Dose (ingestion)	Tumorigenic Concentration (inhalation)
Policylic Aromatic Hydrocarbons (PAHs):	All assessed were in Group II				
Benzo(a)pyrene					1.6 mg/m^3
Benzo(b)fluoranthene					26.7 mg/m^3
Benzo(j)fluoranthene					32 mg/m^3
Benzo(k)fluoranthene					40 mg/m^3
Indeno(1,2,3-cd)pyrene					13.3 mg/m^3
Styrene	Group IV	0.12 mg/kg b.w./day	0.092 mg/m^3		
Tetrachlorobenzenes:					
1,2,4,5-Tetrachlorobenzene	Group IV	0.21 ug/kg b.w./day			
1,2,3,5-Tetrachlorobenzene	Group IV	0.41 ug/kg b.w./day			
1,2,3,4-Tetrachlorobenzene	Group IV	3.4 ug/kg b.w./day			
Tetrachloroethylene	Group IV	0.014 mg/kg b.w./day	0.36 mg/m^3		
Toluene	Group IV	0.22 mg/kg b.w./day	3.8 mg/m^3		
Trichlorobenzenes:					
1,2,4-Trichlorobenzene	Group IV	1.6 ug/kg b.w./day	0.007 mg/m^3		
1,2,3-Trichlorobenzene	Group IV	1.5 ug/kg b.w./day			
1,3,5-Trichlorobenzene	Group IV	1.5 ug/kg b.w./day	3.6 ug/m^3		
Trichloroethylene	Group II			200 mg/kg b.w./day	82 mg/m^3
Xylene, mixed isomers	Group IV	1.5 mg/kg b.w./day	0.18 mg/m^3		

[5] The following categories were used for classification of carcinogens: Group I, carcinogenic to humans; Group II, probably carcinogenic to humans; Group III, possibly carcinogenic to humans; Group IV, unlikely to be carcinogenic to humans; Group V, probably not carcinogenic to humans; and Group VI, unclassifiable with respect to cancer causing ability.

[6] CEPA assumes the following body weights (b.w.) for each age category: 0-6 months, 7 kg; 7 months-4 years, 13 kg; 5-11 years, 27 kg; 12-19 years, 57 kg; 20+ years, 70 kg.

Table A5-6 Toxic concentrations and endpoints for six VOC species, as identified by the California Department of Health Services (1996)

Substance	Concentration (ppm)	Health Effect	Comments and References
Benzene	7.8; 61	Olfactory threshold	(Devos *et al* 1990; AIHA 1989, respectively)
	0.24	Discomfort / mild effect	Transient changes in immune function tests may occur above this concentration (OEHHA 1995)
	1.0	Disability or serious effect	Developing fetus may be harmed above this concentration (OEHHA 1995)
	3,000	Immediately dangerous to life and health (IDLH)	NIOSH (1994)
Formaldehyde	0.87	Olfactory threshold	(Devos *et al* 1990)
	0.14	Discomfort / mild effect	Eye irritation (OEHHA 1995)
	10	Disability or serious effect	Tearing eyes (OEHHA 1995)
	20	IDLH	NIOSH (1994)
Methylene chloride	28	Olfactory threshold	(Devos *et al* 1990)
	24	Discomfort / mild effect	Subtle central nervous system impairment (OEHHA 1995)
	No threshold	Disability or serious effect	OEHHA (1995)
	2300	IDLH	NIOSH (1994)
Styrene	0.14 ; 0.14	Olfactory threshold	(Devos *et al* 1990; AIHA 1989)
	5.1	Discomfort / mild effect	OEHHA (1995)
	No threshold	Disability or serious effect	OEHHA (1995)
	No threshold	IDLH	
Tetrachloro-ethylene	6.2 ; 47	Olfactory threshold	(Devos *et al* 1990; AIHA 1989)
	No threshold	Discomfort / mild effect	
	1.7	Disability or serious effect	Loss of coordination, headache, eye, nose, and throat irritation, and light headiness (OEHHA 1995)
	150	IDLH	NIOSH (1994)
Toluene	1.6 ; 1.6	Olfactory threshold	(Devos *et al* 1990; AIHA 1989)
	9.8	Discomfort / mild effect	OEHHA (1995)
	12.3	Disability or serious effect	Exposure above this concentration may harm a developing fetus (OEHHA 1995)
	2000	IDLH	NIOSH (1994)

Table A5-7 Geometric mean odour thresholds determined by the American Industrial Hygiene Association (AIHA, 1989)

Compound Name	Geometric Mean Air Odour Threshold (ppm)	Type of Threshold[4]	Odour Character	Range of Acceptable Values (ppm)	Range of All Referenced Values (ppm)
Acetaldehyde	0.067	d	pungent/fruity	*	0.0028-1000
Acetic Acid	0.074	d	pungent	0.037-0.15	0.010-31
Acetic Anhydride	<0.14	d	sour/acid	*	0.12-0.36
	0.36	r		*	
Acetone	62	d	sweet/fruity	3.6-653	0.40-800
	130	r		33-699	
Acetonitrile	1160	d	etherish	*	<40-1161
Acetylene	none		gassy	none	226-2584
Acrolein	1.8	d	pungent	*	0.022-1.8
Acrylic Acid	0.092	d	rancid/plastic/sweet	*	0.092-1.0
	1	r		*	
Acrylonitrile	1.6	d	onion/garlic	*	1.6-2.2
Allyl Alcohol	1.7	d	mustard	1.4-2.1	0.51-35
Allyl Chloride	none		pungent	none	0.48-5.9
Ammonia	17	d	pungent/irritating	*	0.043-53
n-Amyl Acetate	0.052	d	banana	*	0.0075-7.3
Aniline	2.4	d	pungent/oily	0.58-10	0.012-10
Arsine	none		garlic	none	<1.0
Benzene	61	d	aromatic/sweet/solvent	34-119	0.78-160
	97	r		*	
Benzyl Chloride	0.041	d	pungent	*	0.041-0.046
Biphenyl	none		pleasant/butter-like	none	0.0095
Boron Trifluoride	none		pungent	none	1.5
Bromine	none		sharp/irritating	none	<0.0099-0.46
Bromoform	none		chloroform/sweet/suffocating	none	0.19-15

Compound Name	Geometric Mean Air Odour Threshold (ppm)	Type of Threshold[4]	Odour Character	Range of Acceptable Values (ppm)	Range of All Referenced Values (ppm)
1,3-Butadiene	0.45	d	aromatic/rubber	*	0.099-76
	1.1	r		*	
Butane	none		natural gas	none	1262-5048
2-Butoxyethanol	0.1	d	sweet/ester/musty	*	0.10-0.35
	0.35	r		*	
n-Butyl Acetate	0.31	d	sweet/banana	0.063-7.4	
	0.68	r		0.038-12	0.0063-368
Butyl Acrylate	none		sweet/rancid/plastic	none	0.00096-0.10
n-Butyl Alcohol	1.2	d	sweet/alcohol	0.12-11	
	5.8	r		1-20	0.05-990
sec-Butyl Alcohol	3.2	d	sweet/alcohol	0.12-13.8	
	0.41	r		*	0.12-26
tert-Butyl Alcohol	960	d	sweet/alcohol	*	3.3-957
n-Butylamine	0.08	d	sour/ammoniacal	*	
	1.8	r		0.24-13.9	0.08-13.9
Butyl Mercaptan	0.001	d	skunk	0.0073-0.001	0.00041-4.9
	0.00073	r			
Camphor	0.079	d	camphorous	*	0.0026-0.96
Carbon Disulphide	none		vegetable sulphide/medicinal	none	0.016-0.42
Carbon Tetrachloride	252	d	sweet/dry cleaner	140-584	1.6-706
	250	r			
Chlorine	0.08	d	suffocating/sharp/bleach	*	0.021-3.4
Chlorine Dioxide	none		chlorine	none	15
Chlorobenzene	1.3	d	almond-like/shoe polish	*	0.087-5.9
Chloroform	192	d	sweet/suffocating	133-276	0.6-1413
B-Chloroprene	none		rubber	none	0.11-138
Cresol	0.0006	d	creosote	0.00005-0.0079	0.000011-0.0068

Compound Name	Geometric Mean Air Odour Threshold (ppm)	Type of Threshold[4]	Odour Character	Range of Acceptable Values (ppm)	Range of All Referenced Values (ppm)
Crotonaldehyde	0.11	d	pungent	0.063-0.2	0.063-0.147
Cumene	0.032	d	sharp/irritating	0.008-0.132	0.0051-1.3
	0.047	r		*	
Cyclohexane	780	d	pungent/solvent/oil	*	0.52-784
Cyclohexanol	0.16	d	camphorous	*	0.058-0.155
Cyclohexanone	3.5	d	sweet/sharp	0.12-100	0.052-219
	0.12	r		*	
Cyclohexene	none			none	0.18
Cyclopentadiene	none		terpene-like/pine/fruit	none	1.8
Decaborane	none		pungent	none	0.06
Diacetone Alcohol	0.27	d	sweet	*	0.27-1.1
	1.1	r		*	
Ciborane	none		repulsive	none	1.8-3.5
o-Dichlorobenzene	0.7	d	camphor	*	0.02-50
p-Dichlorobenzene	0.12	d	camphor/mothballs	*	<15
1,1-Dichloroethane	none		chloroform	none	49-1359
Dicyclopentadiene	0.011	d	sweet/sharp	*	0.003-0.011
	0.02	r		*	
Diethylamine	0.053	d	musty/fishy/amine	0.02-14	0.0033-14.3
	0.75	r		0.06-14.3	
2-Diethylaminoethanol	0.011	d	amine/ammoniacal/sharp	*	0.01-0.25
	0.04	r		*	
Diethyl Ketone	2.8	d	aceton-like/fingernail polish remover	0.85-9.4	0.85-14
	14	r		*	
Diisopropylamine	0.13	d	amine/fishy	*	
	0.38	r		*	0.017-4.2
Dimethylamine	none		ammoniacal/rotten fish	none	0.00076-1.6

Compound Name	Geometric Mean Air Odour Threshold (ppm)	Type of Threshold[4]	Odour Character	Range of Acceptable Values (ppm)	Range of All Referenced Values (ppm)
Dimethylaniline	none		oily	none	0.001-0.2
Dimethyl Formamide	none		fishy	none	0.47-100
1,1-Dimethylhydrazine	9.2	d	fishy	6.1-14	<0.31-14
Dioxane	12	d	sweet/alcohol	0.80-172	
	22	r		1.8-278	0.81-2609
Diphenylamine	none		floral	none	0.022-0.025
Epichlorohydrin	none		chloroform	none	0.08-12
Ethane	none			none	20,328-730,973
2-Ethoxyethanol	2.7	d	sweet/musty	0.3-24	0.3-79
	6.5	r		0.5-279	
2-Ethoxyethyl Acetate	0.06	d	sweet/ester/fruity	*	0.06-0.13
	0.13	r		*	
Ethyl Acetate	18	d	fingernail polish	6.4-50	0.17-190
	32	r		13.3-75	
Ethyl Acrylate	0.00024	d	sweet/ester/plastic	*	0.0002-0.0013
	0.00037	r		*	
Ethyl Alcohol	180	d	sweet/alcohol	49-716	0.34-40,333
	100	r			
Ethylamine	1.27	d	sharp/ammoniacal	*	0.027-3.5
	1.7	r		0.81-3.5	
Ethyl Amyl Ketone	none		solvent/sharp	none	5.9
Ethyl Benzene	none		oily/solvent	none	0.092-0.6
Ethylene	270	d	grassy	*	17-959
	420	r		*	
Ethylene Dichloride	26	d	sweet	6-111	4.3-680
	87	r		41-185	
Ethylene Oxide	420	d	sweet/olefinic	257-690	0.82-690

Compound Name	Geometric Mean Air Odour Threshold (ppm)	Type of Threshold[4]	Odour Character	Range of Acceptable Values (ppm)	Range of All Referenced Values (ppm)
	490	r		493	0.68-2.0
Ethylenimine	none		ammonia	none	18-20
Ethyl Formate	none		aromatic	none	
Ethyl Mercaptan	0.00035	d	rotten cabbage	0.000098-0.003	0.000098-18
	0.0004	r		*	
N-Ethylmorpholine	0.085	d	ammonia	*	0.085-0.25
	0.25	r		*	
Ethyl Silicate	3.6	d	sweet/alcohol	*	
	5	r		*	3.6-85
Fluorine	none		pungent	none	0.097-0.193
Formaldehyde	none		pungent	none	0.027-9770
Formic Acid	none		sharp	none	1.6-340
Furfural	none		bread/almond	none	0.002-0.636
Furfuryl Alcohol	8	d	sweet/ether/alcohol	*	8
Heptane	230	d	gasoline	*	40-547
	330	r		*	
Hexane	none		gasoline	none	65-248
sec-Hexyl Acetate	none		banana	none	0.39
Hydrazine	3.7	d	ammonia	3.0-4.0	3.0-4.0
Hydrogen Chloride	none		sharp/irritating	none	0.255-10.06
Hydrogen Fluoride	none			none	0.04
Hydrogen Selenide	none		garlic	none	0.3
Hydrogen Sulphide	0.0094	d	rotten eggs	0.001-0.13	0.00007-1.4
	0.0045	r		*	
Indene	none			none	0.0042
Iodoform	none		chemical/etherish	none	0
Isoamyl Acetate	0.22	d	banana	0.0034-209	0.00019-1.1

Compound Name	Geometric Mean Air Odour Threshold (ppm)	Type of Threshold[4]	Odour Character	Range of Acceptable Values (ppm)	Range of All Referenced Values (ppm)
Isoamyl Alcohol	none		sweet	none	0.00075-209
Isobutyl Acetate	1.1	d	sweet/ester	0.36-3.6	0.028-0.072
	1.9			0.51-7.2	0.40-7.2
Isobutyl Alcohol	3.6	d	sweet/musty	0.66-40	
	9.8	r		1.8-53	0.012-165
Isophorone	0.19	d	sharp	*	
	0.53	r		*	0.53-0.19
Isopropyl acetate	4.1	d	fruity	0.5-34	
	6.1	r		0.91-41	0.45-41
Isopropyl Alcohol	43	d	sharp/rubbing alcohol	37-610	
	19	r		*	1.0-610
Isopropylamine	0.21	d	ammoniacal/amine	*	
	0.7	r		*	0.21-0.70
Isopropyl Ether	0.017	d	sweet	*	0.017-0.053
	0.053	r		*	
Maleic Anhydride	none		acrid	none	0.25-0.32
Mesityl Oxide	0.017	d	sweet	*	0.017-12
	0.05	r		*	
2-Methoxyethanol	2.4	d	sweet/alcohol	0.096-61	0.096-90
	4.4	r		0.22-90	
2-Methoxyethyl Acetate	0.33	d	sweet/ester	*	0.33-0.64
	0.64	r		*	
Methyl Acetate	180	d	fruity	*	0.17-1733
	300	r		*	
Methyl Acrylate	none		plastic/sharp/airplane glue	none	0.003-0.02
Methylacrylonitrile	6.9	d		*	6.9
Methylamine	4.7	d	fishy	*	0.0009-4.68

Compound Name	Geometric Mean Air Odour Threshold (ppm)	Type of Threshold[4]	Odour Character	Range of Acceptable Values (ppm)	Range of All Referenced Values (ppm)
Methyl Alcohol	160	d	sour/sweet	4.2-5960	3.3-198,656
	690	r		53-8940	
Methyl n-amyl Ketone	none		sweet/mushroom	none	0.18-0.19
N-Methyl Aniline	none			none	1.6-2.0
Methyl n-Butyl Ketone	none		sweet/paint	none	0.068-0.085
Methyl Chloride	none		sweet/etherish	none	>10
Methyl Chloroform	390	d	sweet/etherish	*	16-714
	710	r		*	
Methylene Bisphenyl Isocyanage	none			none	0.39
Methylene Chloride	160	d	sweet	*	1.2-440
	230	r		*	
Methyl Ethyl Ketone	16	d	sweet/sharp	2-85	0.25-85
	17	r		5.4-55	
Methyl Formate	2000	d	ethereal	*	67-2809
	2800	r		*	
Methyl Isoamyl Ketone	0.013	d	sweet/sharp	*	0.0128-0.0492
	0.049	r		*	
Methyl Isobutyl Ketone	0.88	d	sweet/sharp	0.1-7.8	0.10-16
	2.1	r		0.27-16	
Methyl Isocyanate	none			none	2.1
Methyl Isopropyl Ketone	none		sweet/sharp	none	4.3-4.8
Methyl Mercaptan	0.00054	d	rotten cabbage	0.0000002-0.041	0.0000002-0.56
	0.001	r		*	
Methyl Methacrylate	0.049	d	plastic/sharp	*	0.014-0.46
	0.34	r		*	
Methyl Parathion	none		pungent	none	0.0012
Methyl Propyl Ketone	7.7	d		*	3.1-13.6

Compound Name	Geometric Mean Air Odour Threshold (ppm)	Type of Threshold[4]	Odour Character	Range of Acceptable Values (ppm)	Range of All Referenced Values (ppm)
	14	r		*	
Morpholine	0.011	d	fishy/amine	*	0.011-0.070
	0.07	r		*	
Naphthalene	0.038	d	tar/creosote/mothballs	*	0.0095-0.64
Nickel Carbonyl	none		sooty	none	0.5-3
Nitric Acid	none			none	0.27
Nitrobenzene	0.37	d	almonds/shoe polish	0.072-1.9	0.0004-29
Nitrogen Dioxide	none		bleach	none	0.058-0.14
1-Nitropropane	140	d		*	7.7-140
2-Nitropropane	none			none	81-288
N-Nitrosodimethylamine	none			none	0.0079-0.013
Nonane	none		gasoline	none	1-21
Octane	150	d	gasoline, oil	*	15-235
	240	r		*	
Oxygen Difluoride	none			none	0.0996
Ozone	none		pungent/thunderstorm	none	0.0076-0.036
Pentaborane	none		pungent	none	0.97
Pentane	none		sweet	none	119-1147
Perchloroethylene	47	d	etherish	*	2-71
	71	r		*	
Phenol	0.06	d	medicinal/acid/creosote	*	0.0045-1
Phenyl Mercaptan	0.0003	d	putrid	*	0.00003-0.0003
Phosgene	none		haylike	none	0.12-5.7
Phosphine	0.14	r	garlic	*	0.01-5
Phthalic Anhydride	none		choking	none	0.053
Propane	none		natural gas	none	12,225-20,005
Propionic Acid	0.066	d	sour	0.026-0.17	0.00099-1.5

Compound Name	Geometric Mean Air Odour Threshold (ppm)	Type of Threshold[4]	Odour Character	Range of Acceptable Values (ppm)	Range of All Referenced Values (ppm)
	0.033	r		*	
n-Propyl Acetate	0.18	d	sweet/ester	0.048-0.7	1.148-26
	1.9	r		0.14-26	
Propyl Alcohol	5.3	d	sweet/alcohol	0.031-41	<0.031-41
	11	r		0.081-269	
Propylene	23	d	gassy/aromatic	*	10-99
	68	r		*	
Propylene Dichloride	0.26	d	sweet	*	0.26-0.52
	0.52	r		*	
Propylene Glycol Dinitrate	0.24	d		*	0.236
Propylene Glycol Monomethyl Ether	none		etherish ammonia	none	10
Propylene Oxide	45	d	sweet	10-199	10-199
	35	r		*	
Pyridine	0.66	d	burnt/pungent/nauseating	0.23-1.9	0.012-12
	0.74	r			0.23-0.74
Styrene, monomer	0.14	d	sharp/sweet	0.017-1.9	0.0047-61
	0.15	r		*	
Sulphur Dioxide	2.7	d	metallic taste/sharp/irritating	*	0.33-5.0
	4.4	r		*	3.8-5.0
Sulphuric Acid	none			none	0.15
1,1,2,2-Tetrachloroethane	7.3	d	solvent	*	0.233-7.9
Tetrahydrofuran	31	d	ether	*	0.092-61
	61	r		*	
Toluene	1.6	d	sour/burnt	0.16-37	0.021-69
	11	r		1.9-69	
o-Toluidine	none			none	0.025-6.6
m-Toluidine	none			none	0.46-5.9

Compound Name	Geometric Mean Air Odour Threshold (ppm)	Type of Threshold[4]	Odour Character	Range of Acceptable Values (ppm)	Range of All Referenced Values (ppm)
p-Toluidine	none			none	0.027-3.2
1,2,4-Trichlorobenzene	none		aromatic	none	2.96
Trichloroethylene	82	d	ether/solvent	*	0.5-167
	110	r		*	
Triethylamine	0.25	d	fishy/amine	0.10-0.65	0.10-29
	2.8	r		0.27-29	
Trimethylamine	none		fishy/pungent	none	0.00011-0.87
Trimethyl Benzene					
1,2,4-Trimethyl Benzene	2.4	d		*	0.006-2.4
1,3,5-Trimethyl Benzene	2.2	d		*	0.037-2.2
Trimethyl Phosphite	none		pungent	none	0.001
n-Valeraldehyde	none		sickening/decayed/rancid	none	0.0006-8.2
Vinyl Acetate	0.12	d	sour/sharp	*	0.11-0.40
	0.4	r		*	
vinyl chloride	none		sweet	none	10-20
Xylene (o-, m-, p- isomers)	20	d	sweet	*	0.081-40
Dimethylbenzene	40	r		*	
o-xylene	5.4	d		*	0.18-5.4
m-xylene	0.62	d		*	0.081-0.55
p-xylene	2.1	d		*	0.12-2.1

[4] d – detection threshold; r – recognition threshold

Appendix 6: Photochemical Reactivity of VOC in the Atmosphere

Photochemical reaction mechanisms for VOC

In the absence of atmospheric VOCs, ground-level ozone is formed and destroyed in a series of reactions involving nitrogen oxides (NO_x, i.e. the combination of NO and NO_2) (CCME 1997). The ozone-forming reactions under this scenario are as follows:

$$\begin{aligned} NO_2 + h\nu &\rightarrow NO + O \\ O_2 + O + M &\rightarrow O_3 + M \end{aligned}$$

where M represents a third molecule (O_2 or N_2). In the case where VOC species are absent, the formation and destruction of ozone reaches a steady state (CCME 1997).

In the presence of VOCs, however, this reaction is altered significantly. In this situation, VOCs react with hydroxyl radicals (produced photochemically) to produce peroxy radicals; peroxy radicals, in turn, react with NO to produce NO_2. The process can be generalized by the following reactions:

$$\begin{aligned} RH + HO^{\cdot} &\rightarrow R^{\cdot} + H_2O \\ R^{\cdot} + O_2 + M &\rightarrow RO_2^{\cdot} + M \\ RO_2^{\cdot} + NO &\rightarrow RO^{\cdot} + NO_2 \\ RO^{\cdot} + O_2 &\rightarrow HO_2^{\cdot} + (RCHO \text{ and/or } R_1R_2CO) \\ HO_2^{\cdot} + NO &\rightarrow NO_2 + HO^{\cdot} \\ 2\,(NO_2 + h\nu) &\rightarrow 2\,(NO + O) \\ 2\,(O + O_2 + M) &\rightarrow 2\,(O_3 + M) \end{aligned}$$

and the net formula:

$$RH + 4O_2 + h\nu \rightarrow 2O_3 + H_2O + (RCHO \text{ and/or } R_1R_2CO)$$

where RH represents some hydrocarbon or VOC, $HO^{\cdot}$ represents the hydroxyl radical, $HO_2^{\cdot}$ represents a hydroperoxy radical, $R^{\cdot}$ represents an alkyl radical, $RO_2^{\cdot}$ represents an alkylperoxy radical, RCHO represents an aldehyde and R_1R_2CO represents a ketone (CCME 1997). In Alberta, the formation of ground-level ozone is a NO_x-deficient process. As a result, Alberta's cities tend to act as ozone sinks due to elevated concentrations of NO_x from vehicle exhaust (Sandhu 1999).

Effects of the ozone-formation reactions are complex and span further than the production of ground-level ozone from the original VOC. For instance, the products RCHO and R_1R_2CO are themselves substrates for oxidation and will generate additional ozone with each successive cycle of oxidation until the original VOC is completely oxidized to CO_2.

Table A6-1 Maximum Incremental Reactivity (MIR) and Maximum Ozone Reactivity (MOR) values for VOCs at Alberta Environment stations

Family	Year	Edmonton East		Edmonton Central		Calgary Central	
		MIR (µg O_3/g VOC)	MOR (µg O_3/g VOC)	MIR (µg O_3/g VOC)	MOR (µg O_3/g VOC)	MIR (µg O_3/g VOC)	MOR (µg O_3/g VOC)
Alicyclics	1990*	23.61	13.31			6.32	3.55
	1991**	29.56	16.69	9.98	5.59	9.51	5.33
	1992	28.38	16.05	8.40	4.70	6.87	3.85
	1993	25.79	14.37	13.50	7.16	11.17	5.90
	1994	17.52	9.69	10.44	5.61	9.66	5.17
	1995	25.21	14.21	8.32	4.54	10.51	5.66
	1996	19.24	10.72	8.08	4.34	7.77	4.14
	1997	25.18	14.06	9.36	5.06	9.96	5.35
	1998	22.21	12.45	9.18	5.02	9.72	5.29
	1999	19.18	10.70	7.92	4.31	7.47	4.04
	2000	25.16	14.09	9.33	5.07	7.56	4.09
Alkanes	1990*	302.91	185.74			70.05	42.41
	1991**	414.28	254.16	120.92	73.53	115.52	69.68
	1992	440.57	270.96	109.25	66.71	96.47	58.54
	1993	277.62	170.50	113.76	69.51	97.18	59.00
	1994	287.28	175.61	109.65	67.02	97.07	59.04
	1995	305.54	187.63	98.89	60.46	110.83	67.41
	1996	218.55	134.40	87.15	53.28	82.52	50.19
	1997	205.27	125.80	82.74	50.45	92.43	56.08
	1998	244.02	149.97	87.75	53.63	90.46	54.98
	1999	221.68	136.14	73.31	44.70	67.82	41.21
	2000	231.71	142.04	74.71	45.56	62.99	38.24
Alkenes	1990*	100.80	36.80			88.32	33.25
	1991**	98.35	36.68	132.57	49.93	176.46	66.50
	1992	87.56	33.48	85.67	32.75	86.68	33.02
	1993	136.73	53.49	107.47	40.18	113.76	42.83
	1994	340.85	130.46	148.29	40.18	104.63	39.12
	1995	102.41	39.55	148.29	57.73	182.05	70.73
	1996	89.77	34.60	134.94	52.60	149.26	57.94
	1997	113.39	43.28	137.29	53.28	169.71	65.83
	1998	115.42	44.73	166.23	65.13	170.39	66.17
	1999	110.81	43.14	135.85	53.22	127.28	49.63
	2000	113.85	44.29	119.24	46.22	106.64	41.36

* From August 27, 1990 for Edmonton East; from August 9, 1990 for Calgary Central
** From May 18, 1991 for Edmonton Central

Table A6-1 (cont.) **Maximum Incremental Reactivity (MIR) and Maximum Ozone Reactivity (MOR) values for VOCs at Alberta Environment stations**

Family	Year	Edmonton East		Edmonton Central		Calgary Central	
		MIR (µg O_3/g VOC)	MOR (µg O_3/g VOC)	MIR (µg O_3/g VOC)	MOR (µg O_3/g VOC)	MIR (µg O_3/g VOC)	MOR (µg O_3/g VOC)
Alkynes	1990*	4.62	1.80			8.87	3.45
	1991**	4.43	1.72	8.93	3.48	12.08	4.70
	1992	8.08	3.06	10.05	3.91	8.64	3.37
	1993	4.35	1.69	8.88	3.45	8.69	3.38
	1994	4.33	1.67	10.21	3.96	9.52	3.69
	1995	3.61	1.41	7.65	3.00	9.70	3.80
	1996	2.85	1.12	7.94	3.11	8.09	3.17
	1997	5.02	1.97	10.72	4.20	12.51	4.90
	1998	4.45	1.74	9.49	3.72	10.35	4.06
	1999	3.91	1.51	7.75	3.00	7.43	2.87
	2000	5.13	1.99	9.36	3.63	8.23	3.19
Aromatics	1990*	78.81	23.55			92.84	28.70
	1991**	88.31	26.33	161.72	50.08	171.70	53.29
	1992	109.58	33.65	208.97	64.18	146.78	45.20
	1993	180.45	55.36	174.13	53.81	129.81	40.25
	1994	181.14	55.47	142.33	44.12	135.69	41.96
	1995	96.13	28.82	135.71	42.03	180.64	55.64
	1996	76.88	22.88	125.52	38.83	160.51	49.87
	1997	111.70	32.70	126.07	38.65	156.66	48.44
	1998	77.42	23.49	121.79	37.75	160.00	49.70
	1999	67.06	19.84	90.78	27.98	115.13	35.60
	2000	83.16	24.85	105.81	32.73	113.09	34.98
Dienes	1990*	2.24	0.80			4.26	1.52
	1991**	1.82	0.65	6.90	2.45	7.85	2.79
	1992	4.77	1.70	8.31	2.95	7.58	2.70
	1993	3.87	1.38	8.86	3.15	8.45	3.01
	1994	2.83	1.01	7.20	2.56	6.92	2.46
	1995	2.34	0.83	5.24	1.86	7.11	2.53
	1996	2.11	0.75	5.04	1.79	5.92	2.11
	1997	2.13	0.76	4.89	1.74	6.50	2.31
	1998	1.94	0.69	4.91	1.75	5.86	2.08
	1999	2.17	0.77	4.53	1.61	4.62	1.64
	2000	2.63	0.93	4.93	1.75	4.64	1.65

* From August 27, 1990 for Edmonton East; from August 9, 1990 for Calgary Central
** From May 18, 1991 for Edmonton Central

Appendix 7: Summary of Ambient Air Quality Guidelines

Table A7-1 Ontario Ministry of the Environment Ambient Air Quality Criteria for VOC (MOE 2001)

Contaminant Name	Contaminant Code or CAS	Point of Impingement Standard			Ambient Air Quality Criteria (AAQC)				
		Half Hour Point of Impingement Limit (μg/m³)	Point of Impingement Limiting Effect	Standard (S) or Guideline (G)	Annual (μg/m³)	24 Hour (μg/m³)	1 Hour (μg/m³)	10 Minute (μg/m³)	AAQC Limiting Effect
Acetaldehyde	75-07-0	500	Health	G		500			Health
Acetic acid	64-19-7	2500	Odour	S		2500			Odour
Acetone	67-64-1	48000	Odour	S		48000			Odour
Acetophenone	98-86-2	625	Odour	G			1167	850	Health and Odour
Acetylene	74-86-2	56000	Odour	S		56000			Odour
Acrolein	107-02-8	28	Health	G		23.5			Health
Acrylamide	79-06-1	45	Health	S		15			Health
Acrylonitrile	107-13-1	180	Interim	S	0.12	0.6			Health
Adipic acid	124-04-9	3500	Health	G		1167			Health
Alkyltoluene sulphonamide, n-	N/A	100	-	G		120			Particulate
Allyl glycidyl ether	106-92-3	180	Health	G		60			Health
Amyl acetate, iso-	123-92-2					53200			Health and Odour
Amyl acetate, n-	628-63-7					53200			Health and Odour
Amyl acetate, secondary	626-38-0					66500			Health and Odour
Benzene	71-43-2			CARC					Health
Benzo(a)pyrene - single source	50-32-8	0.0033	Health	G	0.00022	0.0011			Health
Benzo(a)pyrene, all sources	50-32-8				0.0003				Health
Benzoic acid	68-85-0	2100	Health	G		700			Health
Benzothiazole	95-16-9	200	Health	G		70			Health
Benzoyl chloride	98-88-4	350	Health	G		125			Corrosion and
Benzyl alcohol	100-51-6	2640	Health	G		880			Health
Biphenyl	92-52-4	60	Odour	G			60		Odour

Contaminant Name	Contaminant Code or CAS	Point of Impingement Standard			Ambient Air Quality Criteria (AAQC)				
		Half Hour Point of Impingement Limit (μg/m^3)	Point of Impingement Limiting Effect	Standard (S) or Guideline (G)	Annual (μg/m^3)	24 Hour (μg/m^3)	1 Hour (μg/m^3)	10 Minute (μg/m^3)	AAQC Limiting Effect
Bromacil	314-40-9	30	Health	G		10			Health
Bromoform	75-25-2	165	Health	G		55			Health
Bromotrifluoromethane (Halon 1301)	75-63-8								Ozone depleting
Butanol, iso-	78-83-1	1940	Odour	G		655	15000	2640	Odour; Health;
Butanol, n-	71-36-3	2278	Odour	G		770	15000	3100	Odour; Irr; Odour
Butanol, tertiary	75-65-0			UD		30300			Health
Butoxy-2-propanol, 1-	5131-66-8	9900	Health	G		3300			Health
Butyl acetate, n-	123-86-4	735	Odour	G		248	15000	1000	Odour; Health;
Butyl acrylate	141-32-2	100		G		120			Particulate
Butyl benzene sulphonamide, n-	3622-84-2	105	Health	G		35			Health
Butyl benzene phthalate	85-68-7	450	Health	G		150			Health
Butyl stearate	123-95-5	100		G		120			Particulate
Captan	133-06-2	75	Health	G		25			Health
Carbon Disulphide	75-15-0	330	Odour	S		330			Odour
Carbon Tetrachloride	56-23-5	7.2	Health	G		2.4			Health
Chloramben	133-90-4	100		G		120			Particulate
Chlordane	57-74-9	15	Health	G		5			Health
Chlorinated dibenzo-p-dioxins (CDDs) (See D/F)	N/A	15 pgTEQ/m^3	Health			5 pgTEQ/m^3			Health
Chlorodifluoromethane (Freon 22)	75-45-6	1050000	Health	G		350000			Health
Chloroform	67-66-3	300	Interim	S	0.2	1			Health
Coal tar pitch volatiles - soluble fraction	8007-45-2	3	Health	G	0.2	1			Health
Cresols	1319-77-3	230	Health	S		75			Health
Cyclohexane	110-82-7	300000	Health	G		100000			Health
Decaborane	17702-41-9	50	Health	S		25			Health
Decane, n	124-18-5			UD			60000		Health and Odour

Contaminant Name	Contaminant Code or CAS	Point of Impingement Standard			Ambient Air Quality Criteria (AAQC)				
		Half Hour Point of Impingement Limit ($\mu g/m^3$)	Point of Impingement Limiting Effect	Standard (S) or Guideline (G)	Annual ($\mu g/m^3$)	24 Hour ($\mu g/m^3$)	1 Hour ($\mu g/m^3$)	10 Minute ($\mu g/m^3$)	AAQC Limiting Effect
Decene, 1-	872-05-9	180000	Health	G		60000			Health
Detergent enzyme (Subtilisin)	1395-21-7	0.2	Health	G		0.06			Health
Diacetone alcohol	123-42-2	990	Odour	G		335		1350	Odour
Diazinon	333-41-5	9	Health	G		3			Health
Dibutyl amine	111-92-2			UD			2645		Health and Odour
Dibutyl phthalate (DBP)	84-74-2	100	Health	G		50			Health
Dibutyltin dilaurate	77-58-7	100	Health	G		30			Health
Dicapryl phthalate	131-15-7	100		S		120			Particulate
Dichloro-1,1,2,2, -tetrafluoroethane, 1,2, (Freon 114)	76-14-2	2100000	Health	G		700000			Health
Dichlorobenzene, ortho-	95-50-1	37000	Health	G			30500		Health
Dichlorobenzene, para-	106-46-7	285	Health	G		95			Health
Dichlorobenzidene, 3,3-	91-94-1			CARC					Health
Dichloroethane, 1,1-	75-34-3	600	Health	G		200			Health
Dichloroethylene, cis-1,2-	156-59-2	315	Health	G		105			Health
Dichloroethylene, sym-1,2-	540-59-0	315	Health	G		105			Health
Dichloroethylene, trans-1,2-	156-60-5	315	Health	G		105			Health
Diethyl amine	109-89-7			UD			2910		Health and Odour
Diethyl phthalate (DEP)	84-66-2	100	Health	G		125			Health
Diethylene glycol monobutyl ether	112-34-5					65			Health
Diethylene glycol monobutyl ether acetate	124-17-4					85			Health
Diethylene glycol monoethyl ether	111-90-0	800	Odour	G		273		1100	Odour
Diethylene glycol monoethyl ether acetate	112-15-2					1800			Health

Contaminant Name	Contaminant Code or CAS	Point of Impingement Standard			Ambient Air Quality Criteria (AAQC)				
		Half Hour Point of Impingement Limit (μg/m^3)	Point of Impingement Limiting Effect	Standard (S) or Guideline (G)	Annual (μg/m^3)	24 Hour (μg/m^3)	1 Hour (μg/m^3)	10 Minute (μg/m^3)	AAQC Limiting Effect
Diethylene glycol monomethyl ether	111-77-3	800	Odour	G		1200			Health
Diethylhexyl phthalate (DEHP)	117-81-7	100	Health	G		50			Health
Difluorodichloromethane (Freon 12)	75-71-8	1500000	Health	G		500000	see "Part VI/EPA"		Health
Dihexyl phthalate (DHP)	84-75-3	100	Health	G		50			Health
Diisobutyl ketone	108-83-8	470	Odour	G		3500		649	Health; Odour
Dimethyl acetamide, n,n-	127-19-5	900	Health	G		300			Health
Dimethyl amine	124-40-3			UD			1840		Health and Odour
Dimethyl disulphide	624-92-0	40	Odour	S			40		Odour
Dimethyl ether	115-10-6	2100	Odour	G		2100			Odour
Dimethyl methylphosphonate	756-79-6					875			Health
Dimethyl phthalate (DMP)	131-11-3	100	Health	G		125			Health
Dimethyl sulfoxide	67-68-5	6300	Health	G		2100			Health
Dimethyl sulphide	75-18-3	30	Odour	S			30		Odour
Dimethyl-1,3-diamino propane, n,n-	109-55-7	60	Health	G		20			Health
Dioctyl phthalate	117-84-0	100	Health	S		120			Particulate
Dioxane	123-91-1			UD		3500			Health
Dioxolane-1,3	646-06-0	30	Health	G		10			Health
Diphenylamine	122-39-4	50	Health	G		17.5			Health
Diquat dibromide -respirable	85-00-7	0.096	Health	G		0.032			Health
Diquat dibromide -total in ambient air	85-00-7	0.48	Health	G		0.16			Health
Dodecyl benzene sulphonic acid	1886-81-3	100		G		120			Particulate
Dodine	2439-10-3	30	Health	G		10			Health
Droperidol	548-73-2	3	Health	G		1			Health
Ethanol (Ethyl alcohol)	64-17-5	19000	Odour	G			19000		Odour
Ethyl acetate	141-78-6	19000	Odour	S			19000		Odour

Contaminant Name	Contaminant Code or CAS	Point of Impingement Standard			Ambient Air Quality Criteria (AAQC)				
		Half Hour Point of Impingement Limit (μg/m^3)	Point of Impingement Limiting Effect	Standard (S) or Guideline (G)	Annual (μg/m^3)	24 Hour (μg/m^3)	1 Hour (μg/m^3)	10 Minute (μg/m^3)	AAQC Limiting Effect
Ethyl acrylate	140-88-5	4.5	Odour	S			4.5		Odour
Ethyl benzene	100-41-4	3000	Health	S		1000		1900	Health; Odour
Ethyl ether	60-29-7	7000	Interim	S		8000		950	Health and Odour
Ethyl hexanol, 2-	104-76-7	600	Odour	G			600		Odour
Ethyl-3-ethoxy propionate	763-69-9	147	Odour	G		50		200	Odour
Ethylanthraquinone, 2-	84-51-5	30	Health	G		10			Health
Ethylene	74-85-1			UD		40			Vegetation
Ethylene dibromide	106-93-4	9	Health	G		3			Health
Ethylene dichloride	107-06-2	6	Health	G	0.4	2			Health
Ethylene glycol	107-21-1					12700			Health
Ethylene glycol butyl ether (Butyl cellosolve)	111-76-2	350	Odour	G		2400		500	Health;Odour
Ethylene glycol butyl ether acetate (But.cell.ace)	112-07-2	500	Odour	G		3250		700	Health;Odour
Ethylene glycol dinitrate	628-96-6	10	Health	G		3			Health
Ethylene glycol ethyl ether (Cellosolve)	110-80-5	800	Odour	G		380		1100	Health;Odour
Ethylene glycol ethyl ether acetate (Cell.ace.)	111-15-9	220	Odour	G		540		300	Health;Odour
Ethylene glycol monohexyl ether	112-25-4					2500			Health
Ethylene oxide	75-21-8	15	Health	G		5			Health
Ethylenediaminetetra acetic acid	60-00-4	100		G		120			Particulate
Fentanyl citrate	990-73-8	0.06	Health	G		0.02			Health
Ferric oxide	1309-37-1	75	Soiling	S		25			Soiling
Formaldehyde	50-00-0	65	Odour	S		65			Health
Formic acid	64-18-6	1500	Health	S		500			Health
Furfural	98-01-1	1000	Odour	S			1000		Odour
Furfuryl alcohol	98-00-0	3000	Health	S		1000			Health
Glutaraldehyde	111-30-8	42	Health	G		14	35		Health

Contaminant Name	Contaminant Code or CAS	Point of Impingement Standard			Ambient Air Quality Criteria (AAQC)				
		Half Hour Point of Impingement Limit (µg/m^3)	Point of Impingement Limiting Effect	Standard (S) or Guideline (G)	Annual (µg/m^3)	24 Hour (µg/m^3)	1 Hour (µg/m^3)	10 Minute (µg/m^3)	AAQC Limiting Effect
Haloperidol	52-86-8	0.3	Health	G		0.1			Health
n-Heptane	142-82-5	33000	Health	S		11000			Health
Hexachlorocyclopentadiene	77-47-4	6	Health	G		2			Health
Hexamethyl disilazane	999-97-3	5	Health	G		2			Health
Hexamethylene diisocyanate monomer	822-06-0	1.5	Health	G		0.5			Health
Hexamethylene diisocyanate trimer	4035-89-6	3	Health	G		1			Health
Hexamethylenediamine	124-09-4	48	Health	G		16			Health
Hexamethyleneimine	111-49-9	945	Health	G		315			Health
Hexane	110-54-3	35000	Health	G		12000			Health
Hexylene glycol	107-41-5	14400	Health	G			12000		Health and Irr.
Isobutyl acetate	110-19-0	1220	Odour	G		412		1660	Odour; Odour
Isopropyl ether	108-20-3	220	Odour	G		110000			Health
Isopropyl acetate	108-21-4	1470	Odour	G		500		2000	Odour; Odour
Isopropyl benzene	98-82-8	100	Odour	S		400			Health
Lindane (Hexachlorocyclohexane)	58-89-9	15	Health	G		5			Health
Malathion	121-75-5	100		G		120			Particulate
Maleic anhydride	108-31-6	100	Health	G		30			Health
Mercaptans (as Methyl mercaptan) -total	74-93-1	20	Odour	S			20		(A) Odour
Mercaptobenzothiazole disulphide	120-78-5	100		G		120			Particulate
Mercury (as Hg) - alkyl compounds	7439-97-6	1.5	Health	S		0.5			Health
Metaldehyde (Acetaldehyde tetramer)	108-62-3	100		G		120			Particulate
Methacrylic acid	79-41-4	2000	Odour	G		2000			Odour

Contaminant Name	Contaminant Code or CAS	Point of Impingement Standard			Ambient Air Quality Criteria (AAQC)				
		Half Hour Point of Impingement Limit ($\mu g/m^3$)	Point of Impingement Limiting Effect	Standard (S) or Guideline (G)	Annual ($\mu g/m^3$)	24 Hour ($\mu g/m^3$)	1 Hour ($\mu g/m^3$)	10 Minute ($\mu g/m^3$)	AAQC Limiting Effect
Methane diphenyl diisocyanate (MDI)	101-68-8	3	Health	G		1			Health
Methanol (Methyl alcohol, Wood alcohol)	67-56-1	12000	Health	S		4000			Health
Methoxy-1-propyl acetate,2-	70657-70-4	4600	Health	G		1530			Health
Methoxychlor	72-43-5	100		G		120			Particulate
Methyl acrylate	96-33-3	4	Odour	S			4		Odour
Methyl bromide	74-83-9	4000	Health	G		1350			Health
Methyl chloride	74-87-3	20000	Health	G		7000			Health
Methyl ethyl ketone (2-Butanone)	78-93-3	30000	Interim	S		1000			Health
Methyl ethyl ketone peroxide	1338-23-4	250	Health	G		80	200		Health; Health
Methyl isobutyl ketone	108-10-1	1200	Odour	S		1200			Odour
Methyl methacrylate	80-62-6	860	Odour	S		860			Odour
Methyl salicylate	119-36-8	300	Health	G		100			Health
Methyl styrene, alpha	98-83-9			UD			24000		Health
Methyl tert-butyl ether	1634-04-4	2200	Odour	G		7000			Health
Methyl-2-hexanone, 5-	110-12-3	460	Odour			160		630	Odour
Methyl-2-pyrrolidone, n-	872-50-4						40000		Health
Methyl-n-amyl ketone	110-43-0			UD		4600			Health
Methylal	109-87-5	18000	Health	G		6200			Health
Methylcyclopentadienyl manganese tricarbonyl	12108-13-3	30	Health	G		10			Health
Methylene chloride	75-09-2	5300	Interim	G	44	220			Health; Health
Methylene dianiline	101-77-9	30	Health	G		10			Health
Methylene iodide	75-11-6	195	Health	G		65			Health
Methylene-bis-2-chloroaniline, 4,4-	101-14-4	30	Health	G		10			Health
Miconazole nitrate	22832-87-7	15	Health	G		5			Health
Monochlorobenzene	108-90-7	4200	Health	G			3500	4500	Health; Odour

Contaminant Name	Contaminant Code or CAS	Point of Impingement Standard			Ambient Air Quality Criteria (AAQC)				
		Half Hour Point of Impingement Limit (µg/m^3)	Point of Impingement Limiting Effect	Standard (S) or Guideline (G)	Annual (µg/m^3)	24 Hour (µg/m^3)	1 Hour (µg/m^3)	10 Minute (µg/m^3)	AAQC Limiting Effect
Monomethyl amine	74-89-5	25	Odour	S		25			Odour
Naphthalene	91-20-3	36	Odour	G		22.5		50	Health. Odour
Naphthol, alpha-	90-15-3	100	Health	G		100			Health
Nickel carbonyl	13463-39-3	1.5	Health	S		0.5			Health
Nitrilotriacetic acid	139-13-9	100		S		120			Particulate
Nitrogen oxides (see NOx)	10102-44-0	500	Health	S		200	400		(A) Health; Health
Nitrogylcerin	55-63-0	10	Health	G		3			Health
Nitrosodiethylamine, n-	55-18-5			CARC					Health
Nitrosodimethylamine, n-	62-75-9			CARC					Health
Octane	111-65-9	45400	Odour	G		15300		61800	Odour,Odour
Octene, 1-	25377-83-7	150000	Health	G		50000			Health
Oleic acid	112-80-1	6	Health	G			5		Health
Oxalic acid	144-62-7	75	Health	G		25			Health
Oxo-heptyl acetate	90438-79-2	255	Health	G		85			Health
Oxo-hexyl acetate	88230-35-7	255	Health	G		85			Health
Paraquat dichloride - respirable	1910-42-5	0.009	Health	G		0.003			Health
Paraquat dichloride - total in ambient air	1910-42-5	0.045	Health	G		0.015			Health
Penicillin	1406-05-9	0.3	Health	G		0.1			Health
Pentachlorophenol	87-86-5	60	Health	G		20			Health
Perchloroethylene	127-18-4	UD	Health	G		360			Health
Phenol	108-95-2	100	Health	S		100			Health
Phosgene	75-44-5	130	Health	S		45			Health
Phosphine	7803-51-2	30	Health	G		10			Health
Phthalic anhydride	85-44-9	100		S		120			Particulate
Pimozide	2062-78-4	3	Health	G		1			Health
Polybutene -1-sulphone	N/A	100		G		120			Particulate

Contaminant Name	Contaminant Code or CAS	Point of Impingement Standard			Ambient Air Quality Criteria (AAQC)				
		Half Hour Point of Impingement Limit (µg/m^3)	Point of Impingement Limiting Effect	Standard (S) or Guideline (G)	Annual (µg/m^3)	24 Hour (µg/m^3)	1 Hour (µg/m^3)	10 Minute (µg/m^3)	AAQC Limiting Effect
Polychlorinated biphenyls (PCBs)	1336-36-3	0.45	Health	G	0.035	0.15			Health
Polychloroprene	25267-15-6	100		G		500			Particulate
Propanol, iso- (Isopropyl alcohol, Isopropanol)	67-63-0	24000	Odour	G		24000			Odour
Propanol, n- (Propyl alcohol)	71-23-8	48000	Health	G		16000			Health
Propionaldehyde	123-38-6	7	Odour	G		2.5		10	Odour; Odour
Propionic acid	79-09-04	100	Odour	G			100		Odour
Propionic anhydride (as Propionic acid)	123-62-6	100	Odour	G			100		Odour
Propyl acetate, n-	109-60-4	900	Odour	G		6600			Health
Propylene dichloride	78-87-5	2400	Odour	S		2400			Odour
Propylene glycol	57-55-6	100	Health	G		120			Health
Propylene glycol methyl ether	107-98-2	89000	Odour	G		30000		121000	Odour; Odour
Propylene glycol monomethyl ether acetate	108-65-6	5000	Odour	G		5000			Odour
Propylene oxide	75-56-9	450	Interim	S	0.3	1.5			Health; Health
Pyridine	110-86-1	60	Odour	G		150		80	Health; Odour
Quinone	106-51-4	45	Health	G		15			Health
Styrene	100-42-5	400	Odour	S		400			Odour
Sulfamic acid	5329-14-6	100		G		120			Particulate
Sulphur dioxide	7446-09-5	830	Health	S	55	275	690		(A) Health and Vegetation
Tetrabutylurea	4559-86-8	30	Health	G		10			Health
Tetrahydrofuran	109-99-9	93000	Odour	S		93000			Odour
Tetramethyl thiuram disulphide	137-26-8	30	Health	G		10			Health
Thiourea	62-56-6	60	Health	G		20			Health
Toluene	108-88-3	2000	Odour	S		2000			Odour
Toluene diisocyanate	584-84-9	1	Health	S		0.5			Health
Tributyltin oxide	56-35-9	0.42	Health	G		0.14			Health

Contaminant Name	Contaminant Code or CAS	Point of Impingement Standard			Ambient Air Quality Criteria (AAQC)				
		Half Hour Point of Impingement Limit (µg/m^3)	Point of Impingement Limiting Effect	Standard (S) or Guideline (G)	Annual (µg/m^3)	24 Hour (µg/m^3)	1 Hour (µg/m^3)	10 Minute (µg/m^3)	AAQC Limiting Effect
Trichlorobenzene, 1,2,4-	120-82-1	100		G		400			Irr;Health
Trichloroethane, 1,1,1,- (Methyl chloroform)	71-55-6	350000	Health	S		115000			Health
Trichloroethylene	79-01-6	3500	Interim	S	23	115			Health
Trichlorofluoromethane	75-69-4	18000	Health	G		6000	see "Part VI/EPA"		Health
Trifluoroacetic acid	76-05-1	45	Health	G		15			Health
Trifluorotrichloroethane	76-13-1	2400000	Health	S		800000	see "Part VI/EPA"		Health
Trimethyl amine	75-50-3	0.5	Odour	G			0.5		Odour
Trimethylbenzene, 1,2,4-	95-63-6	500	Odour	G		1000			Odour and Health
Trimethylol propane	77-99-6	100	Health	G		1250			Health
Tripropyltin methacrylate	N/A	3	Health	G		1			Health
Vinyl chloride	75-01-4	3	Health	G	0.2	1			Health
Vinylidene chloride (1,1-Dichloroethene)	75-35-4	30	Health	S		10			Health
Warfarin	81-81-2	30	Health	G		10			Health
Xylenes	1330-20-7	2300	Odour	S		2300			Odour

TERMS:
S = Air Quality Standard
G = Guideline
CARC = Carcinogen
UD = Under Development, or odour threshold review
Int = Interim

Table A7-2 Québec Ministry of the Environment air quality criteria (Environnement Québec 1999)

Name	CAS	15 min Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Acetaldehyde	75-07-0					0.5	q
Acetone	67-64-1					180	RfD
Acetonitrile	75-05-8					70	NOAEL
Acetophenone	98-86-2	830	Odour			350	RfD
Acrolein	107-02-8					0.02	RfC
Acrylamide	79-06-1					0.0008	Cancer
Acrylic Acid	79-10-7					1	RfC
Acrylonitrile	107-13-1					0.01	q
Allyl Alcohol	107-18-6					9	RfD
Isobuytl Alcohol	78-83-1					500	RfD
Allyl Chloride	107-05-1					1	RfC
Ammonia	7664-41-7					100	RfC
Aniline	62-53-3					1	RfC
Antimony and its compounds	7440-36-0					0.3	RfD
Antimony Trioxide	1309-64-4					0.2	RfC
Anthracene	120-12-7					500	RfD
Silver and its soluble compounds	7440-22-4					2 and 0.2	RfD
Arsenic and its soluble compounds	7440-38-2					0.0002	q
Arsine	7784-42-1					0.05	RfC
Benzaldehyde	100-52-7					200	RfD
Benzene	71-43-2					0.1	q
p-Benzidine	92-87-5					0.00002	q
Benzo(a)pyrene	50-32-8					0.0009	q
Beryllium and its compounds	7440-41-7					0.0004	q
PCBs	1336-36-3					0.01	q
Boron and its compounds	7440-42-8					40	LOAEL/SF
Bromomethane	74-83-9					5	RfC
Bromoform	75-25-2					0.9	q
1,3-Butadiene	106-99-0					0.004	q
n-Butanol	71-36-3					200	RfD
tert-Butyl methyl ether	1634-04-4	2200	Odour				
Di-n-butyl phthalate	84-74-2					0.5	NOAEL/SF
Cadmium and its compounds	7440-43-9					0.0006	q

Name	CAS	15 min Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Carbon disulfide	75-15-0	50	Odour			700	RfC
Carbon tetrachloride	56-23-5					0.07	q
Chlorine dioxide	10049-14-4					0.2	RfC
2-Chloroacetophenone	523-27-4					0.03	RfD
Chlorobenzene	108-90-7					28	ADL
Chloroform	67-66-3					0.04	Cancer
o-Chlorotoluene	95-49-8					30	RfD
bis-Chloromethyl ether	542-88-1					0.000016	q
Chromium VI	18540-29-9					0.00008	Cancer
Cobalt	7440-48-4					0.03	MRL
Cumene	98-82-8	430	Odour			400	RfD
Cyclohexanone	108-94-1					3520	Odour
Cyclohexylamine	108-91-8					350	RfD
Decabromyldiphenyl ether	1163-19-5					30	RfD
1,4-Dibromobenzene	106-37-6					30	RfD
Dibromochloromethane	124-48-1					30	RfD
Di-n-butyl phthalate	84-74-2					0.5	RfD
1,2-Dibromo-3-chloropropane	96-12-8					0.2	RfC
o-Dichlorobenzene	95-50-1					1500	ADL
p-Dichlorobenzene	106-46-7	1080	Odour			160	RfD
trans-1,2-Dichloroethane	156-60-5					79	LOAEL/SF
Dichloroethyl ether	111-44-4					0.003	q
1,1-Dichloroethane	75-34-3					123	
1,2-Dichloroethane	107-06-2					0.04	RfD
2,4-Dichlorophenol	120-83-2					3	RfD
1,3-Dichloropropene	542-75-6					20	RfC
Di(2-ethylhexyl)adipate	103-23-1					400	RfD
Di(2-ethylhexyl)phthalate	117-81-7					14	RfD
Dimethylamine	124-40-3					2	LOAEL (HEC)
n,n-Dimethylaniline	121-69-7					3.5	RfD
Dimethylformamide	68-12-2					30	RfC
m-Dinitrobenzene	99-650					0.2	RfD
2,4-Dinitrotoluene	121-14-2					3	RfD
Epichlorohydrine	106-89-8					0.8	q
1,2-Epoxybutane	106-88-7					20	RfC
Ethyl ether	60-29-7					27	Odour

Name	CAS	15 min Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
2-Ethoxyethanol	110-80-5	800	Odour			200	RfC
Ethyl benzene	100-41-4					1000	RfC
Ethyl acetate	141-78-6					1600	RfD
Ethyl chloride	75-00-3	10920	Odour			10000	RfC
Ethylene dibromide	106-93-4					0.005	q
Ethylene dichloride	107-06-2					0.04	q
Ethylene glycol	107-21-1					2000	TLV
Ethylene oxide	75-21-8					0.01	Cancer
Formaldehyde	50-00-0	37	Odour			0.08	q
Hexachlorobenzene	118-74-1					0.002	Cancer
Hexachlorobutadiene	87-68-3					0.05	q
Hexachlorocyclopentadiene	77-47-4					10	RfD
Hexachloroethane	67-72-1					0.3	q
1,6-Hexamethylene diisocyanate	822-06-0					0.01	RfC
n-Hexane	100-54-3					200	RfC
2-hexanone	591-78-6					36.8	LOAEL/SF
Hydrogen chloride	7647-01-0					20	RfC
Hydrogen cyanide	74-90-8					0	RfC
Hydrogen fluoride	7664-39-3					0.4	LOAEL/SF
Hydrogen sulfide	7783-06-4					1	RfC
Manganese, compounds and dust	7439-96-5					0.05	RfC
Mercury, vapour	7439-97-6					0.15	RfC
Methyl methacrylate	80-62-6	340	Odour			50	ADL
Methanethiol	74-93-1	1.4	Odour				
Methanol	67-56-1	2600	Odour			437	RfD
2-methoxyethanol	109-86-4					20	RfC
Methyl n-butyl ketone	591-78-6	310	Odour			35	LOAEL/SF
Methyl bromide	74-83-9					5	RfD
Methyl chloride	74-87-3					825	MRL
Methyl methacrylate	80-62-6	340	Odour			50	ADL
Methylene bi-(phenylic isocyanate-4)	101-68-8					0.6	RfC
Methylene chloride	75-09-2					2	q
Methyl ethyl ketone	78-93-3	5800	Odour			820	RfC
Methyl formate	107-31-3					369	LOAEL/SF
Methyl alcohol	67-56-1	2600	Odour			440	RfD
Methyl mercaptan	74-93-1					1.4	NOAEL/SF

Name	CAS	15 min Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Napthalene	91-20-3	200	Odour			3	LOAEL (HEC)
Nickel and its compounds	7440-02-0					0.0025	q
Nickel sulfide	12035-72-2					0.002	q
Nitrobenzene	98-95-3					2.5	RfD
2-Nitropropane	79-46-9					20	RfC
N-Nitroso-di-n-butylamine	924-16-3					0.0006	q
n-Nitrosodiethylamine	55-18-5					0.00002	q
n-Nitrosodimethylamine	62-75-9					0.00007	q
n-Nitrosopyrrolidine	930-55-2					0.002	q
PM10	DMA-41						
PM2.5	DMA-42						
PCDD and PCDF	DMA-14					0.0000005	ADL
Pentachlorophenol	87-86-5					0	q
Perchloroethylene	127-18-4					250	LOAEL/SF
Phenol	108-95-2	150	Odour			20	NOAEL/SF
Phosphine	7803-51-2					0.3	RfC
Phosphoric Acid	7664-38-2					10	RfC
Lead	7439-92-1					0.01	LOAEL/SF
Propylene glycol monomethyl ether	107-98-2					2000	RfC
Propylene dichloride	78-87-5					4	RfC
Propylene oxide	75-56-9					0.3	q
Pyrene	129-00-0					50	RfD
Pyridine	110-86-1					1.8	RfD
Stoddard, solvent	8052-41-3					60	LOAEL/SF
Styrene	100-42-5	200	Odour				
1,2,3,4-Tetrachlorobenzene	634-66-2					12	ADL
1,2,3,5-Tetrachlorobenzene	634-90-2					1.7	ADL
1,2,4,5-Tetrachlorobenzene	95-94-3					0.6	ADL
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6	50 pg/m^3				0.5 pg/m^3	ADL
1,1,1,2-Tetrachloroethane	630-20-6					0.1	Cancer
1,1,2,2-Tetrachloroethane	79-34-5					0.02	Cancer
Tetrachloroethylene	127-18-4					20	RfD
Carbon Tetrachloride	56-23-5					1	RfD
1,1,1,2-Tetrafluoroethane	811-97-2					80000	RfC
Toluene	108-88-3	1000	Odour			400	RfD
Toxaphene	8001-35-2					0.003	q

Name	CAS	15 min Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
1,2,3-Trichlorobenzene	87-61-6					3.5	ADL
1,3,5-Trichlorobenzene	108-70-3					2.7	ADL
1,2,4-Trichlorobenzene	120-82-1					18	RfD
1,1,1-Trichloroethane	71-55-6					1100	NOAEL/SF
1,1,2-Trichloroethane	79-00-5					0.06	Cancer
Trichloroethylene	79-01-6					2.3	q
2,4,5-Trichlorophenol	95-95-4					200	RfD
2,4,6-Trichlorophenol	88-06-2					0.3	q
1,2,3-Trichloropropane	96-18-4					10	RfD
Triethylamine	121-44-8					7	RfC
Vanadium	7440-62-2					1	ADL
Vanadium pentoxide	1314-62-1					0.08	LOAEL/SF
Vinyl acetate	108-05-4					200	RfC
Vinyl bromide	593-60-2					3	RfC
Vinyl chloride	75-01-4					0.2	q
Vinylidene chloride	75-35-4					0.02	Cancer
Xylene (o-, m- and p- isomers)	1330-20-7	350	Odour				

*Cancer: Concentration corresponding to an additional risk of cancer of 10-6.
ADL: Allowable Daily Limit.
LOAEL: Lowest Observable Adverse Effect Level.
LOAEL/SF: LOAEL divided by a safety factor.
LOAEL(HEC): LOAEL, adjusted for differences in dose between species for a human equivalent concentration.
MRL: Minimum Risk Level.
NIOSH/100, NIOSH/50 or ACGIH/50: Recommendations for occupational exposure, divided by safety factors of 100 or 50.
NOAEL: No observed adverse effect level.
NOAEL/SF: NOAEL divided by a safety factor.
q*: Slope factor: quantitative analysis of cancer risk, concentrations for an added risk of 1 case per million individuals exposed over a lifetime.
RfD: Reference dose.
RfC: Reference concentration.
TLV: Threshold Limit Value.

Table A7-3 Québec Ministry of the Environment provisional management criteria (Environnement Québec 1999)

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Acetic acid	64-19-7	1175	Odour							
Acetic anhydride	108-24-7	400	NIOSH/50							
Acetone cyanohydrine	75-86-5	40	NIOSH/100							
Acetonitrile	75-05-8								50	RfC
Acetylene	74-86-2	265	NIOSH/100							
Acetylene tetrabromide	79-27-6				140	ACGIH/100				
Adipic acid	124-04-9						1167	ONT		
Mineral alcohols	DMA-07						10000	ONT		
Aldrin	309-00-2				25	NIOSH/100				
n-Alkyltoluene sulphonamide	DMA-20						120	ONT,P		
Allyl propyl disulfide	2179-59-1	360	NIOSH/50		240	NIOSH/50				
Allyl Alcohol	107-18-6	200	NIOSH/50							
Allyl glycidyl ether	106-92-3	180					60			
Aluminum oxide	1344-28-1						120	Particles		
Aluminum alkyls	7429-90-5-F				40	NIOSH/50				
Aluminum - respirable fraction	7429-90-5-C				100	NIOSH/100				
Aluminum - welding smoke	7429-90-5-E				100	NIOSH/100				
Aluminum - pyrophosphate powder	7429-90-5-D				100	NIOSH/100				
Aluminum - distearate	300-92-5	100								
Aluminum - total metal dust	7429-90-5-B						120	Particles		
Aluminum - stearate	7047-84-9	100								
Aluminum - tristearate	637-12-7	100								
Aluminum - soluble salts	7429-90-5				40	NIOSH/50				
Starch (total dust)	9005-25-8						120	Particles		
2-Aminopyridine	504-29-0				20	NIOSH/100				
Ammonium chloride	12125-02-9						120	Particles		
Ammonium perfluorooctanoate	3825-26-1				1	ACGIH/100				
Ammonium sulfamate (total dust)	7773-06-0						120	Particles		
n-Amyl acetate	628-63-7	285	Odour							
sec-Amyl acetate	626-38-0	10.5	Odour							
Anisidine (o-, p- isomers)	29191-52-4				5	NIOSH/100				

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Antimony and its compounds	7440-36-0	75			5	NIOSH/100				
Silver, metal and soluble compounds	7440-22-4	3			0.1	NIOSH/100				
Atrazine	1912-24-9				50	NIOSH/100				
Nitrogen trifluoride	7783-54-2				290	NIOSH/100				
Barium - soluble compounds	7440-39-3	30			10	NIOSH/50				
Barium cyanide	542-62-1									
Barium sulfate (total dust)	7727-43-7						120	Particles		
Benzoic acid	65-85-0	2100					700			
Benzothiazole	95-16-9	200					70			
Benzoyl chloride	98-88-4	350					125			
Benzoyl peroxide	94-36-0				100	NIOSH/50				
Benzyl chloride	100-44-7	100	NIOSH/50		100	NIOSH/50				
Benzylic alcohol	100-51-6	2640					880			
Biphenyl	92-52-4	5	Odour							
Chlorinated Biphenyl (42%)	53469-21-9	0.02								
Chlorinated Biphenyl	11097-69-1	0.02								
Chlorinated Biphenyl oxide	55720-99-5				10	NIOSH/50				
Boron oxide	1303-86-2						120	Particles		
Boron tribromide	10294-33-4	100	NIOSH/50				35			
Boron trichloride	10294-34-5	100					35			
Boron trifluoride	7637-07-2	5					2			
Boric acid	10043-35-3	100					33			
Coal tar (volatile) - soluble fraction	65996-93-2	3					1		0.1	
Bromacil	314-40-9	30					10			
Bromine	7726-95-6	70			14	NIOSH/50	20			
Bromine pentafluoride	7789-30-2				14	NIOSH/50				
Butane	106-97-8				38	NIOSH/50				
Butanethiol	109-79-5	3.5	Odour							
n-butanol	71-36-3	2510	Odour							
2-Butoxy-1-propanol	5131-66-8	9900					3300			
2-Butoxyethanol	111-76-2	480	Odour		240	NIOSH/100				
2-(2-Butoxyethoxy)ethanol acetate	124-17-4						85			

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
2-(2-Butoxyethoxy)ethanol	112-34-5						65			
2-Butoxyethyl acetate	112-07-2									
Butylamine	109-73-9	300								
n-Butylbenzene sulfonamide	3622-84-2	105					35			
n-Butyl acetate	123-86-4	1850	Odour							
sec-Butyl acetate	105-46-4				19000	NIOSH/50				
tert-Butyl acetate	540-88-5				19000	NIOSH/50				
Butyl acrylate	141-32-2	0.18	Odour				120	ONT,P		
Benzyl butyl phthalate	85-68-7	450								
tert-Butyl chromate	1189-85-1				0.01	NIOSH/100				
n-Butyl lactate	138-22-7				500	NIOSH/100				
Butyl stearate	123-95-5						120	ONT,P		
sec-Butylic alcohol	78-92-2	7880	Odour		6100	NIOSH/50				
tert-Butylic alcohol	75-65-0				6000	NIOSH/50				
n-Butyl glycidyl ether	75-65-0	300	NIOSH/100							
o-sec-Butylphenol	89-72-5				600	NIOSH/50				
p-ter-Butyltoluene	98-51-1	2400	NIOSH/50		1200	NIOSH/50				
Limestone (total dust)	1317-65-3						120	Particles		
Calcium carbonate	471-34-1						120	Particles		
Calcium carbide	75-20-7	20					10			
Calcium cyanamide	156-62-7				10	NIOSH/50				
Calcium cyanide	592-01-8	50	NIOSH/100							
Calcium hydroxide	1305-62-0	27	ONT				13.5			
Calcium oxide	1305-78-8	20	ONT				10			
Calcium stearate	1592-23-0	100	ONT				35			
Calcium sulfate (total dust)	7778-18-9						120	Particles		
Camphor - synthetic	76-22-2				20	NIOSH/100				
Caprolactam (dust)	105-60-2				10	NIOSH/100				
Caprolactam (vapours)	105-60-2-B				10	NIOSH/100				
Captan	133-06-2	75			25					
Carbaryl	63-25-2				50	NIOSH/100				
Carbofuran	1563-66-2				1	NIOSH/100				
Carbon - black	1333-86-4	25					10			
Carbon tetrabromide	558-13-4				14	NIOSH/100				
Carbonyl fluoride	353-50-4	150	NIOSH/100		50	NIOSH/100				

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Catechol	120-80-9				200	NIOSH/100				
Cellulose (total dust)	9004-34-6						120	Particles		
Cesium hydroxide	21351-79-1				40	NIOSH/50				
Ketene	463-51-4				18	NIOSH/50				
Chlorambene	133-90-4						120	NIOSH/100		
Chlorine	7782-50-5	100			30	NIOSH/50				
Chlorine cyanide	506-77-4				12	NIOSH/50				
Chlorine trifluoride	7790-91-2	8	NIOSH/50							
1-Chloro-1-nitropropane	600-25-9				100	NIOSH/100				
Chloroacetaldehyde	107-20-0	60	NIOSH/50							
Chloroacetyl chloride	79-04-9	4	NIOSH/50							
o-Chlorobenzilidene malononitrile	2698-41-1	8	NIOSH/50							
Chloropicrin	76-06-2				14	NIOSH/50				
b-Chloroprene	126-99-8	36	NIOSH/100							
o-Chlorostyrene	2039-87-4				2850	NIOSH/100				
o-Chlorotoluene	95-49-8	1660	Odour							
Chromates and chromic acids	7440-47-3-F				0.01	NIOSH/100				
Chromium, Cr II	7440-47-3-B									
Chromium, Cr III	7440-47-3-C				5	NIOSH/100				
Chromium, Cr VI - soluble compounds	7440-47-3-D									
Chromium metal	7440-47-3				5	NIOSH/100				
Chromyl chloride	14977-61-8				0.01	NIOSH/100				
Citric acid	77-92-9				120					
Cobalt carbonyl	10210-68-1				2	NIOSH/50				
Cobalt hydrocarbonyl	16842-03-8				2	NIOSH/50				
Cotton dust	DMA-04				2	NIOSH/100				
Cresol (all isomers)	1319-77-3	1	Odour							
Crotonaldehyde	4170-30-3	340	Odour		120	NIOSH/50				
Copper	7440-50-8	100			20	NIOSH/50				
Cyanamide	420-04-2				40	NIOSH/50				
Cyanogen	460-19-5				400	NIOSH/50				
Cyclohexane	110-82-7	300000			21000	NIOSH/50				
Cyclohexanol	108-93-0	610	Odour							

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Cyclohexanone	108-94-1	3500	Odour		1000	NIOSH/50				
Cyclohexene	110-83-8	600	Odour							
Cyclohexylamine	108-91-8				800	NIOSH/50				
Cyclopentadiene	542-92-7	5100	Odour		4000	NIOSH/50				
Cyclopentane	287-92-3				17200	NIOSH/100				
Decaborane	17702-41-9	50			3	NIOSH/100				
n-Decane	124-18-5			60000						
1-Decene	872-05-9	180000					60000			
Di-(ethyl-2 hexyl) phthalate	117-81-7				50	NIOSH/100				
Di-n-octyl phthalate	117-84-0						120	ONT,P		
2,6-Di-tert-butyl-p-cresol	128-37-0				100	NIOSH/50				
Diacetonalcohol	123-42-2	335	Odour							
Diazinon	333-41-5	9			1	NIOSH/100				
Diazomethane	334-88-3				6.8	NIOSH/50				
2,2-Dibenzothiazyl disulfide	120-78-5						120	ONT,P		
Diborane	19287-45-7	20			2	NIOSH/50				
Dibutylamine	111-92-2			2645						
2-Dibutylaminoethanol	102-81-8				280	NIOSH/100				
Dibutyl phosphate	107-66-4				100	NIOSH/50				
Dibutyltin dilaurate	77-58-7	100					30			
Dicapryl phthalate	131-15-7	100								
Dichloroacetylene	7572-29-4	4	NIOSH/100							
Dichlorodifluoromethane	75-71-8				99000	NIOSH/50				
1,3-Dichloro-5,5-dimethylhydantoine	118-52-5	8	NIOSH/50		4	NIOSH/50				
1,2-Dichloroethylene	540-59-0	315					105			
Dichlorofluoromethane	75-43-4	1500000			800	NIOSH/50				
1,1-Dichloro-1-nitroethane	594-72-9				100	NIOSH/100				
Dichlorphos	62-73-7								0.5	RfC
Dicyclopentadiene	77-73-6	30	Odour							
Diethanolamine	111-42-2				260	ACGIH/50				
Diethylamine	109-89-7	385	Odour		300	NIOSH/100				
Diethylaminoethanol	100-37-8	50	Odour							
Diethyl ketone	96-22-0	7000	Odour							
Diethyl phthalate	84-66-2	100			50	NIOSH/100				

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Diethylene triamine	111-40-0				40	NIOSH/100				
Difluorodibromomethane	75-61-6				17200	NIOSH/50				
Diglycidylic ether	2238-07-5				5	NIOSH/100				
Dihexyl phthalate	84-75-3	100					50			
Diisobutyl ketone	108-83-8	635	Odour							
Diisopropylamine	108-18-9				400	NIOSH/50				
Dimethyl acetamide	127-19-5	900			350	NIOSH/100	300			
Dimethylamine	124-40-3				360	NIOSH/50				
Dimethylaniline	121-69-7	60	Odour							
2,2-Dimethylbutane	75-83-2	18000	NIOSH/50		3500	NIOSH/100				
2,3-Dimethylbutane	79-29-8	18000	NIOSH/50		3500	NIOSH/100				
Dimethyl disulfide	624-92-0									
Dimethyl ether	115-10-6	2100								
Dimethyl methylphosphonate	756-70-6						875			
Dimethyl phthalate	131-11-3				100	NIOSH/50				
Dimethyl sulfate	77-78-1	12.5			5	NIOSH/100				
Dimethyl disulfide	624-92-0									
Dimethyl ether	115-10-6	2100								
Dimethyl methylphosphonate	756-70-6						875			
Dimethyl phthalate	131-11-3				100	NIOSH/50				
Dimethyl sulfate	77-78-1	12.5			5	NIOSH/100				
Dimethyl sulfide	75-18-3									
Dimethyl sulfoxide	67-68-5	6300					2100			
1,1-Dimethylhydrazine	57-14-7				1.5	NIOSH/100				
n,n-Dimethyl-1,3-propanediamine	109-57-7	60					20			
4,6-Dinitro-o-cresol	DMA-32				2	NIOSH/50				
m-Dinitrobenzene	99-65-0				10	NIOSH/100				
o-Dinitrobenzene	528-29-0				10	NIOSH/100				
p-Dinitrobenzene	100-25-4				10	NIOSH/100				
2,4-Dinitrophenoxyacetic acid	DMA-33				100	NIOSH/100				
3,5-Dinitro-o-toluamide	148-01-6				50	NIOSH/100				
Dinitrotoluene	25321-14-6				15	NIOSH/100				
2,4-Dinitrotroluene	121-14-2				15	NIOSH/100				
Dioxane	123-91-1	36	NIOSH/100							

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Dinitrotoluene	25321-14-6				15	NIOSH/100				
2,4-Dinitrotoluene	121-14-2				15	NIOSH/100				
Dioxane	123-91-1	36	NIOSH/100							
1,3-Dioxolane	646-06-0	30					10			
Diphenylamine	122-39-4	50					17.5			
Dipropyl ketone	123-19-3				2350	NIOSH/100				
Dipropylene glycol methyl ether	34590-94-8	210	Odour		100	NIOSH/100				
Diquat dibromide (inhalable)	85-00-7	0.096					0.032			
Diquat dibromide (total ambient)	85-00-7-B	0.48					0.16			
Disulfiram	97-77-8				20	NIOSH/100				
Divinylbenzene	1321-74-0				500	NIOSH/100				
Divinylbenzene	1321-74-0				500	NIOSH/100				
Dodecyl benzene sulfonic acid	1886-81-3						120	ONT,P		
Dodine	2439-10-3	30					10			
Droperidole	548-73-2	3					1			
Tin, organic compounds	7440 31-5-B				1	NIOSH/100				
Tin and inorganic compounds (except SnH4)	7440-31-5	30			40	NIOSH/50	10			
Tin oxide	18282-10-5				40	NIOSH/50				
Ethanethiol	75-08-1	1.8	Odour							
Ethanol	64-17-5	340	Odour							
Ethanolamine	141-43-5				160	NIOSH/100				
2-Ethoxyethyl acetate	111-15-9	220			27	NIOSH/100				
2-(2-Ethoxyethoxy)ethanol	111-90-0	800	Odour							
2-(2-Ethoxyethoxy)ethanol acetate	112-12-5						1800			
Ethyl acetate	141-78-6	14000	Odour							
Ethyl acrylate	140-88-5	4.5	Odour							
Ethylamine	75-04-7				360	NIOSH/50				
Ethyl (sec)-amyl ketone	106-68-3				1300	NIOSH/100				
2-Ethylanthraquinone	84-51-5	30					10			
Ethyl bromide	74-96-4	13810	Odour							
Ethylbutyl ketone	106-35-4				4600	NIOSH/50				
Ethylene	74-85-1						40			
Ethylene glycol dinitrate	628-96-6	10					1	NIOSH/100		

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Ethylene chlorhydrine	107-07-3	30	NIOSH/100							
Ethylene glycol	107-21-1	2500	ACGIH STEL/50				12700			
Ethylenediamine tetraacetic acid	60-00-4						120	ONT,P		
Ethyleneimine	151-56-4				8.8	ACGIH/100				
Ethyl formate	109-94-4				6000	NIOSH/50				
2-Ethyl-1-hexanol	104-76-7	370	Odour							
Ethylidene norbornene	16219-75-3	65	Odour							
Ethylic ether	60-29-7	26980	Odour							
n-Ethylmorpholine	100-74-3				2300	NIOSH/50				
Ethyl-3-ethoxy propionate	763-69-9	147	Odour				50	Odour		
Ethyl silicate	78-10-14				1700	NIOSH/50				
Fentanyl citrate	990-73-8	0.06					0.02			
Iron chloride	7705-08-0				10	ACGIH/50				
Iron oxide (smoke and dust)	1309-37-1	75					25			
Iron nitrate	10421-48-4				10	ACGIH/100				
Iron pentacarbonyl	13463-40-6	4.5	ACGIH/100		2.5	ACGIH/100				
Iron - soluble salts	DMA-08				10	NIOSH/100				
Iron sulfate	10028-22-5				10	NIOSH/100				
Ferrous chloride	7758-94-3				10	NIOSH/100				
Ferrous sulfate	7720-78-7				10	NIOSH/100				
Ferrocene	102-54-5				100	NIOSH/100				
Ferrovanadium (dust)	12604-58-9	30	NIOSH/100		10	NIOSH/100				
Glass fibre (dust)	DMA-28				50	NIOSH/100				
Fluorine	7782-41-4				2	NIOSH/50				
Formic acid	64-18-6				180	NIOSH/50				
Furfural	98-01-1	300	Odour		79	ACGIH/100				
Furfurylic alcohol	98-00-0	1200	NIOSH/50		800	NIOSH/50				
Gallium arsenide	1303-00-0	0.02	NIOSH/50							
Germanium tetrahydride	7782-65-2				6	NIOSH/50				
Glutaraldehyde	111-30-8	42			8	NIOSH/100				
Glycerine	56-81-5				100	NIOSH/100				
Glycidol	556-52-5				750	NIOSH/100				
Glycolonitrile	107-16-4	100	NIOSH/100							
Grain, dust	DMA-29				40	NIOSH/100				

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Graphite - inhalable dust	7782-42-5				25	NIOSH/100				
Gypsum (total dust)	13397-24-5				100	NIOSH/100				
Hafnium and its compounds	7440-58-6				5	NIOSH/100				
Haloperidole	52-86-8	0.3					0.1			
n-Heptane	142-82-5	1800	NIOSH/100		3500	NIOSH/100				
Hexachlorocyclopentadiene	77-47-4								0.07	RfC prov
Hexachlorodibenzeo-p-dioxin (mixture)	19408-74-3								0	q
Hexachloronaphthalene	1335-87-1				2	NIOSH/100				
Hexafluoroacetone	684-16-2				7	NIOSH/100				
Hexamethyl disilazane	999-97-3	5					2			
Hexamethylene diisocyanate	4035-89-6	3					1			
Hexamethyleneimine	111-49-9	945					315			
sec-Hexyl acetate	108-84-9	12	Odour							
Hexyleneglycol	107-41-5	14400								
Mineral Oils	8012-95-1						120	Particles		
Hydrazine	302-01-2	0.4	NIOSH/100							
Hydrogen bromide	10035-10-6	200	NIOSH/50							
Hydrogen peroxide	7722-84-1	90					30			
Hydrogen selenide	7783-07-5				3.2	NIOSH/50				
Hydroquinone	123-31-9	40	NIOSH/50							
2-Hydroxypropyl acrylate	25584-83-2	56	NIOSH/50							
Indene	95-13-6	70	Odour							
Indium and its compounds	7440-74-6				1	NIOSH/100				
Iodine	7553-56-2	20	NIOSH/50							
Isoamyl acetate	123-92-2	265	Odour							
Isoamylic alcohol	123-51-3	150	Odour							
Isobutyl acetate	110-19-0	3040	Odour							
Isobutylic alcohol	78-83-1	4850	Odour							
Isooctylic alcohol	26952-21-6				5320	NIOSH/50				
Isophorone diisocyanate	4098-71-9	1.8	NIOSH/50		0.45	NIOSH/50				
Isopropoxyethanol	109-59-1				1060	ACGIH/100				
Isopropylamine	75-31-0				120	ACGIH/100				
n-Isopropylaniline	768-52-5				100	NIOSH/100				
Isopropyl acetate	108-21-4	1470	Odour				500			

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Isopropylic alcohol	67-63-0	12250	NIOSH/100		9800	NIOSH/100				
Isopropylic ether	108-20-3	70	Odour							
Isopropylic glycidyl ether	4016-14-2	2380	NIOSH/100							
Kaolin (total dust)	1332-58-7						120	Particles		
Kerosene	8008-20-6	550	Odour							
Mineral wool - total dust	DMA-30						120	Particles		
Lindane	58-89-9	15			5	NIOSH/100				
Lithium (excluding hydrides)	7439-93-2	60					20			
Lithium hydride	7580-67-8	7.5			0.5	NIOSH/100				
Magnesium carbonate (total dust)	546-93-0						120	Particles		
Magnesium oxide (smoke)	1309-48-4						120	Particles		
Magnesium stearate	557-04-0	100					35			
Malathion	121-75-5						120	ONT,P		
Maleic anhydride	108-31-6	100			20	NIOSH/100				
Malononitrile	109-77-3				80	NIOSH/100				
Manganese, tricarbonyl cyclopentadienyl	12079-65-1				1	NIOSH/100				
Marble	DMA-05						120	ONT,P		
Mercury (alkyls)	7439-97-6-B	0.3	NIOSH/100		0.1	NIOSH/100				
Mercury (aryls and inorganic compounds)	7439-97-6-C	5			1	NIOSH/100				
Mesityl oxide	141-79-7	1805	Odour							
Methacrylic acid	79-41-4	2000	Odour							
Methoxychlor	72-43-5						120	ONT,P		
2-Methoxyethyl acetate	110-49-6				5	NIOSH/100				
2-(2-Methoxyethoxy)ethanol	111-77-3	800	Odour							
2-Methoxy-1-propyl acetate	70657-70-4	4600					1530			
4-Methoxyphenol	150-76-5				50	NIOSH/100				
Methyl acetylene	74-99-7				16400	ACGIH/100				
Methylacrylonitrile	126-98-7				27	ACGIH/100				
Methylal	109-87-5	18000					6200			
Methylamine	74-89-5	25	Odour							
Methylamyl ketone	110-43-0	1630	Odour							
n-Methylaniline	100-61-8				20	NIOSH/100				

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Methylcyclohexane	108-87-2				16000	NIOSH/100				
Methylcyclohexanol	25639-42-3				2340	ACGIH/100				
o-Methylcyclohexanone	583-60-8	3440	ACGIH/100		2290	ACGIH/100				
2-Methylcyclopentadienyl tricarbonyl manganese	12108-13-3				2	NIOSH/100				
Methyl hydrazine	60-34-4	0.38	NIOSH/100		0.8	NIOSH/100				
Methyl 2-cyano acrylate	137-05-3	320	NIOSH/50		160	NIOSH/50				
Methyl acetate	79-20-9	13935	Odour							
Methyl acrylate	96-33-3	16.5	Odour							
Methyl formate	107-31-3	7500	NIOSH/50		4920	NIOSH/50				
Methyl salicylate	119-36-8	300					100			
Methyl silicate	681-84-5				120	NIOSH/50				
Methylene Bi-(4-cyclohexylisocyanate)	5124-30-1	2.2	NIOSH/50		1.1	NIOSH/50				
Methylene iodide	75-11-6	195					65			
4,4-methylene bi-(2-chloro aniline)	101-14-4	30			0.03	NIOSH/100				
4,4-Methylene bianiline	101-77-9	30					10			
Methylethyl ketone peroxide	1338-23-4	15	NIOSH/100							
Methylisoamyl ketone	110-12-3	55	Odour							
Methyl isobutyl carbinol	108-11-2	290	Odour							
Methylisobutyl ketone	108-10-1	1200	Odour							
Methylisopropyl ketone	563-80-4	6690	Odour							
2-Methylpentane	107-83-5	18000	NIOSH/100		3500	NIOSH/100				
3-Methylpentane	96-14-0	18000	NIOSH/100		3500	NIOSH/100				
2-Methylpropanenitrile	78-82-0				220	ACGIH/100				
Methylpropyl ketone	107-87-9				5300	NIOSH/100				
a-Methyl styrene	98-83-9	1400	Odour							
n-Methyl-n,2,4,6-tetranitroaniline	479-45-8				30	NIOSH/50				
Mica (inhalable fraction)	12001-26-2				30	NIOSH/100				
Miconazole nitrate	22832-87-7	15					5			
Molybdenum and its compounds	7439-98-7				50	NIOSH/100				
Morpholine	110-91-8	35	Odour							
Naphtha	8030-30-6				4000	NIOSH/100				

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Maphthalene diisocyanate	25551-28-4	3.4	NIOSH/50		0.8	NIOSH/50				
1-Naphthol	90-15-3	100								
Nickel carbonyl	13463-39-3				0.07	NIOSH/100				
Nickel (soluble compounds)	7440-02-0-B				0.15	NIOSH/100				
Nickel (metal)	7440-02-0				0.15	NIOSH/100				
Nitrapyrin	1929-82-4	200	NIOSH/100		100	NIOSH/100				
Nitrous oxide	10024-97-2				300	NIOSH/100				
Nitrilotriacetic acid	139-13-9						120	ONT,P		
Nitric acid	7697-37-2	100					35			
Nitric oxide	10102-43-9	380	Odour							
p-Nitroaniline	100-01-6				30	NIOSH/100				
Nitroethane	79-24-3	6445	Odour							
Nitroglycerine	55-63-0	10			1	NIOSH/100				
Nitromethane	75-52-5	8735	Odour							
1-Nitropropane	108-03-2				900	NIOSH/100				
m-Nitrotoluene	99-08-1	250	Odour		110	NIOSH/100				
o-Nitrotoluene	88-72-2				110	NIOSH/100				
p-Nitrotoluene	99-99-0				110	NIOSH/100				
Nonane	111-84-2				10500	NIOSH/100				
2-Methoxyaniline	90-04-0				5	ACGIH/100				
Octachloronaphthalene	2234-13-1	3	NIOSH/100		1	NIOSH/100				
Octane	111-65-9	18000	NIOSH/100		3500	NIOSH/100				
1-Octene	25377-84-7	150000					50000			
Oleic acid	112-80-1	6								
Osmium tetreoxide	20816-12-0	0.06	NIOSH/100		0.02	NIOSH/100				
Oxalic acid	144-62-7	40	NIOSH/100		20	NIOSH/50				
Oxo-heptyl acetate	90438-97-2	255					85			
Oxo-hexyl acetate	88230-35-7	255					85			
Oxygen difluoride	7783-41-7	2	NIOSH/50							
Palladium (soluble compounds)	7657-10-1	30					10			
Paraquat - inhalable fraction	4685-14-7-B				2	NIOSH/50				
Paraquat - total dust	4685-14-7				10	ACGIH/50				
Paraquat Dichloride - inhalable	1910-42-5	0.009					0.003			
Paraquat Dichloride - total ambient	1910-42-5-B	0.045					0.015			

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Parathion	5638-2				0.5	NIOSH/100				
Parafin	8002-74-2				40	NIOSH/100				
Pentaborane	19624-22-7	0.3	NIOSH/100		0.1	NIOSH/100				
Pentachloronaphthalene	1321-64-8				5	NIOSH/100				
Pentaerythritol	115-77-5						120	Particles		
Pentane	109-66-0	18000	NIOSH/100		3500	NIOSH/100				
Perchloromethanethiol	594-42-3	7.5	Odour							
Perchloryle fluoride	7616-94-6	280	NIOSH/100		140	NIOSH/100				
Perfluoroisobutylene	382-21-8	0.82	ACGIH/100							
Phenol (solid)	108-95-2-B	100					100			
m-Phenylenediamine	108-45-2				1	NIOSH/100				
o-Phenylenediamine	95-54-5				1	NIOSH/100				
p-Phenylenediamine	106-50-3				1	NIOSH/100				
Phenylhydrazine	100-63-0	4	Odour							
Phenylic ether (vapour)	101-84-8	8	Odour							
Phenylphosphine	638-21-1	2.3	ACGIH/100							
Phosgene	75-44-5	8	NIOSH/100		4	NIOSH/100				
Phosphorus (yellow)	7723-14-0				1	NIOSH/100				
Phosphorus oxychloride	10025-87-3	30	NIOSH/100		6	NIOSH/100				
Phosphorus pentachloride	10026-13-8	30			17	ACGIH/50				
Phosphorus trichloride	7719-12-2	56	ACGIH/50		22	NIOSH/50				
Phthalic anhydride	85-44-9								120	RfC
m-Phthalodinitrile	626-17-5				100	NIOSH/50				
Picric acid	88-89-1	0.5	Odour							
Pimozide	2062-78-4	3					1			
Piperazine dihycrochloride	142-64-3				50	NIOSH/50				
Platinum, metal	7440-06-4				20	NIOSH/50				
Platinum (soluble salts)	7440-06-4-B				0.04	NIOSH/50				
Plaster of Paris (total dust)	26499-65-0						120	Particles		
Lead (chromate oxide)	18454-12-1									
Lead, tetramethyl	75-74-1				0.75	NIOSH/100				
Lead, tetraethyl	78-00-2				0.75	NIOSH/100				
Polybutene-1-sulfone	DMA-11						120	ONT,P		
Polychloroprene	25267-15-6						120	ONT,P		
Potassium cyanides	151-50-8	50	NIOSH/100							

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Potassium hydroxide	1310-58-3	28					14			
Potassium nitrate	7757-79-1						120	ONT,P		
Propane	74-98-6				18000	NIOSH/100				
Propargyl alcohol	107-19-7				20	NIOSH/100				
beta-Propiolactone	57-57-8				15	NIOSH/100				
Propionaldehyde	123-38-6	7					2.5			
Propionic acid	79-09-4	100	Odour							
Propionitrile	107-12-0				140	NIOSH/100				
n-Propyl acetate	109-60-4	900	Odour							
Propylene glycol	57-55-6	100								
Propylene glycol dinitrate	6423-43-4				3	NIOSH/100				
Propyleneglycol monomethyl ether acetate	108-65-6	5000								
Propyleneimine	75-55-8				47	NIOSH/100				
Propylic alcohol	71-23-8	6385	Odour							
Pyridine	110-86-1	60	Odour							
Quinone	106-51-4	45			4	NIOSH/100				
Sodic resin	8050-09-7	1	NIOSH/100							
Resorcinol	108-46-3	900	NIOSH/100		450	NIOSH/100				
Rhodium (soluble compounds)	7440-16-6-C				0.01	NIOSH/100				
Rhodium (smoke and dust)	7440-16-6-B				1	NIOSH/100				
rhodium, metal	7440-16-6				1	NIOSH/100				
Selenium and its compounds	7782-49-2				2	NIOSH/100				
Selenium hexafluoride	7783-79-1				8	NIOSH/50				
Silica (crystalline)	DMA-18				1	ACGIH/50				
Silica (amorphous, melted)	60676-86-0				0.5	NIOSH/100				
Silica (amorphous, smoke)	69012-64-2				20	ACGIH/100				
Silica (amorphous, precipitated and hardened)	7699-41-4				60	NIOSH/100				
Silica (amorphous, diatomaceous earth - containing less than 1% crystalline silica)	61790-53-2				60	NIOSH/100				
Silica, crystalline (cristobalite)	14464-46-1				0.5	NIOSH/100				
Silica, crystalline (quartz)	14808-60-7				0.5	NIOSH/100				
Silica, crystalline (tridymite)	15468-32-3				0.5	NIOSH/100				

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Silica, crystalline (Tripoli)	1317-95-9				0.5	NIOSH/100				
Silicium (total dust)	7440-21-3						120	Particles		
Silicium carbide (total dust)	409-21-2						120	Particles		
Silicium tetrahydride	7803-62-5				132	NIOSH/50				
Sodium pyrophosphate	7722-88-5				100	NIOSH/50				
Sodium nitride	26628-22-8	2.9	NIOSH/100							
Sodium disulfite	7631-90-5				100	NIOSH/100				
Sodium chlorate	7775-09-9	18					6			
Sodium chlorite	7758-19-2	60					20			
Sodium cyanide	142-33-9	50	NIOSH/100							
Sodium fluoroacetate	62-74-8	1.5	NIOSH/100		0.5	NIOSH/100				
sodium hydroxide	1310-73-2	20					10			
Sodium metabisulfite	7681-57-4				100	NIOSH/50				
Sodium nitrate	7631-99-4	100								
Sodium, tetraborate salt (anhydrous and pentahydrate)	DMA-27				10	NIOSH/100				
Sodium, tetraborate salt (decahydrate)	1303-96-4				50	NIOSH/100				
Sodium tetrafluoride	DMA-19				4	ACGIH/100				
Sulfur hexafluoride	2551-62-4	59700	NIOSH/100							
Sulfur monochloride	10025-67-9	120	NIOSH/50							
Sulfur pentafluoride	5714-22-7	1	NIOSH/50							
Sulfur tetrafluoride	7783-60-0	8	NIOSH/50							
Tin dichloride	7772-99-8	30					10			
Steatite - total dust (<1% crystalline silica)	DMA-31				60	NIOSH/100				
Steatite - inhalable fraction (<1% crystalline silica)	DMA-31-B				30	NIOSH/100	20	Particles		
Strontium	7440-24-6						120	ONT,P		
Strontium carbonate	1633-05-2						120	ONT,P		
Strontium chromate	7789-06-2				0.05	NIOSH/100				
Strontium hydroxide	18480-07-4						120	ONT,P		
Strontium oxide	1314-11-0						120	ONT,P		
Volatiles	1395-21-7				0.0002	NIOSH/50				
Succinonitrile	110-61-2				200	NIOSH/100				

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Sucrose (total dust)	57-50-1						120	Particles		
Sulfamic acid	5329-14-6						120	Particles		
Sulfuric acid	7664-93-9				20	NIOSH/100				
Sulfuryl fluoride	2699-79-8	800	NIOSH/50		400	NIOSH/50				
Tantalum - metal	7440-25-7	100	NIOSH/100		50	NIOSH/100				
Tellurium and its compounds	13494-80-9				1	NIOSH/100				
Tellurium hexafluoride	7783-80-4				2	ACGIH/50				
Terebenthine	8006-64-2	560000	Odour							
m-Terphenyl	92-06-8	100	NIOSH/50							
o-Terphenyl	84-15-1	100	NIOSH/50							
p-Terphenyl	92-94-4	100	NIOSH/50							
Terphenyls, hydrogenated	61788-32-7				49	ACGIH/100				
Tetrabutyl-urea	4559-86-8	30					10			
Tetrachloronaphthalene	1335-88-2				20	NIOSH/100				
Tetrahydrofuran	109-99-9	5895	Odour							
Tetramethyl succinonitrile	3333-52-6				28	ACGIH/100				
tetranitromethane	509-14-8				160	NIOSH/50				
Thallium, metal and soluble compounds	7440-28-0				1	NIOSH/100				
Thioglycolic acid	68-11-1				38	NIOSH/100				
Thionyl chloride	7719-09-7	100	NIOSH/50							
Thiourea	62-56-6	60					20			
Thiram	137-26-8	30			10	NIOSH/100				
Titanium	7440-32-6						120	ONT,P		
Titanium dioxide	13463-67-7	100					34			
o-Tolidine	119-93-7				0.2	NIOSH/100				
Tolmetin Sodium	35711-34-3	15					5			
Toluene-2,4-diisocyanate	584-84-9	1			0.36	ACGIH/100				
m-Toluidine	108-44-1				88	ACGIH/100				
o-Toluidine	85-53-4				88	ACGIH/100				
p-Toluidine	106-49-0				88	ACGIH/100				
1,1,1-Tris(hydroxymethyl)propane	77-99-6	100								
Tributyl phosphate	126-73-8				25	NIOSH/100				
Tributyltin oxide	56-35-9	0.42					0.14			

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Trichloroacetic acid	76-03-9				134	ACGIH/50				
Trichlorofluoromethane	75-69-4	18000					6000			
Trichloronaphthalene	1321-65-9				50	NIOSH/100				
Trifluoracetic acid	76-05-1	45					15			
Trifluorobromomethane	75-63-8				61000	NIOSH/100				
Trimellitic anhydride	552-30-7				0.39	ACGIH/100				
Trimethylamine	75-50-3	0.5	Odour							
Trimethylbenzene	25551-13-7				1230	ACGIH/100				
1,2,3-Trimethylbenzene	526-73-8				1230	ACGIH/100				
1,3,5-Trimethylbenzene	108-67-8	2700			1230	ACGIH/100				
1,2,4-Trimethylbenzene	95-63-6	500	Odour		1230	ACGIH/100				
Trimethyl phophite	121-45-9	0.5	Odour				120	ONT,P		
2,4,6-Trinitrotoluene	118-96-7				5	NIOSH/100				
Triorthocresyl phosphate	78-30-8				1	NIOSH/100				
Triphenylamine	603-34-9				100	NIOSH/100				
Triphenyl phosphate	115-86-6				30	NIOSH/100				
Tripropyltin methacrylate	DMA-16	3					1			
Tungsten, soluble compounds	7440-33-7-B	30	NIOSH/100		10	NIOSH/100				
Tungsten, metal and insoluble compounds	7400-33-7	100	NIOSH/100		50	NIOSH/100				
Uranium, soluble and insoluble compounds	7440-61-1	6	NIOSH/100		2	NIOSH/100				
n-Valeraldehyde	110-62-3				1750	NIOSH/100				
Vinyl fluoride	75-02-5	94	NIOSH/100		18.8	NIOSH/100				
Vinylcyclohexene	100-40-3				4	ACGIH/100				
Vinylcyclohexene dioxide	106-87-6				570	ACGIH/100				
Vinylidene fluoride	75-38-7	130	NIOSH/100		26	NIOSH/100				
Vinyltoluene	25013-15-4	4800	NIOSH/100		2420	NIOSH/100				
VM & P Naphtha	8032-32-4	3.9	Odour							
Warfarin	81-81-2	30					10			
m-Xylene	108-38-3	4775	Odour							
m-Xylene a,a-diamine	1447-55-0	1	NIOSH/100							
Xylidine (isomers)	1300-73-8	24	Odour							
Yttrium	7440-65-5				20	NIOSH/50				
Zinc	7440-66-6						120	ONT,P		

Name	CAS	15 min Max. (ug/m^3)	Basis*	1 hr Max. (ug/m^3)	8 hr Max. (ug/m^3)	Basis*	24 hr Max. (ug/m^3)	Basis*	Annual Max. (ug/m^3)	Basis*
Zinc chloride (smoke)	7646-85-7	12					10			
Zinc chromate	13530-65-9				0.01	NIOSH/100				
Zinc (yellow)	37300-23-5				0.1	ACGIH/100				
Zinc oxide (smoke)	1314-13-2	100	NIOSH/100		50	NIOSH/100				
Zinc potassium chromate	1103-86-9				0.1	NIOSH/100				
Zinc stearate (total dust)	555-05-1	100					35			

Cancer: Concentration corresponding to an additional risk of cancer of 10-6.
ACGIH: American Conference of Governmental and Industrial Hygienists
ADL: Allowable Daily Limit.
LOAEL: Lowest Observable Adverse Effect Level.
LOAEL/SF: LOAEL divided by a safety factor.
LOAEL(HEC): LOAEL, adjusted for differences in dose between species for a human equivalent concentration.
MRL: Minimum Risk Level.
NIOSH/100, NIOSH/50 or ACGIH/50: Recommendations for occupational exposure, divided by safety factors of 100 or 50.
NOAEL: No observed adverse effect level.
NOAEL/SF: NOAEL divided by a safety factor.
q: Slope factor: quantitative analysis of cancer risk, concentrations for an added risk of 1 case per million individuals exposed over a lifetime.
RfD: Reference dose.
RfC: Reference concentration.
TLV: Threshold Limit Value.

Table A7-4 Complete listing of Texas Natural Resource Conservation Commission Effects Screening Levels (TNRCC 2001)

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
Abamectin	0.4	0.04
Abate, respirable	50	5
acenaphthene*	1	0.1
acetal	4924	492
acetaldehyde (odor)	90	9
acetamide	320	32
acetic acid	250	25
acetic anhydride	200	20
acetoacetoxyethyl methacrylate,2-	2000	200
acetone	5900	590
acetone cyanohydrin	40	4
acetonitrile	340	34
acetophenone	490	49
acetyl chloride	4	0.4
acetylacetone (odor)	41	4
acetylene	26620	2660
acetylene dichloride	7930	793
acetylene tetrabromide	140	14
acetylsalicylic acid	50	5
Acifluorfen, particulate	50	5
acridine	0.5	0.05
acrolein**	2.3	0.23
Acrylamide	0.3	0.03
acrylic acid	60	6
acrylic acid, ethyl ester (odor)	5	0.5
acrylic acid, methyl ester (odor)	58	5.8
acrylic acid, n-butyl ester (odor)	183	18.3
acrylic polymer	40	4
Acryloid	50	5
acrylonitrile**	43	4.3
adamantane	100	10
adipic acid	50	5
adiponitrile	88	8.8
Admire	33	3.3
Affirm	0.4	0.04
Aflatoxin	0.8	0.08
alcohol ethoxylates	600	60
Aldrin	2.5	0.25
aliphatic diisocyanate	0.25	0.025
aliphatic esters	500	50
alkanes (C4-C16), not otherwise specified	3500	350
alkanes, C17 and higher	100	10
alkenyl succinic anhydride	240	24
alkyd resins	100	10
alkyl phenol ethoxylate	600	60
alkyl phenol, C-20	1150	115
alkylates	1750	175
allyl alcohol**	48	4.8
allyl chloride**	30	3
allyl glycidyl ether	47	4.7
allyl methacrylate	110	11
allyl propyl disulfide	120	12
allyl succinic anhydride	6	0.6
allylamine**	12	1.2
alumina	50	5
aluminum alkyls and soluble salts	20	2
aluminum pyro powders, welding fumes	50	5
aluminum: metal and oxide	50	5
Amdro	14	1.4
amino-1,2,4-triazole, 3-	2	0.2
amino-3-aminomethyl-3,3,5-trimethylcyclohexane	375	38
aminoethanol	75	7.5
aminoethoxyethanol	380	38
aminoethyl piperazine	10	1
aminoethylethanolamine	640	64
1-(2-aminoethyl)-2-n-alkyl imidazoline	50	5
2-amino-2-methyl-1-propanol	400	40
aminopropyl morpholine, 4-	1650	165
aminopyridine, 2-	19	2
aminopyridine, 3-	15	1.5
aminopyridine, 4-	2.5	0.25
Amitraz	35	3.5
Amitrole	2	0.2
ammonia*,**	170	17

Substance	Short-term ESL (µg/m^{3})	Long-term ESL (µg/m^{3})
ammonium acetate	220	22
ammonium chloride fume	100	10
ammonium fluoride (as HF, 3hr)	4.9	0.5
ammonium hydroxide	170	17
ammonium nitrate	10	1
ammonium nitrite	50	5
ammonium perfluorooctanoate	0.1	0.01
ammonium persulfate, particulate	10	1
ammonium sulfamate, particulate	50	5
ammonium sulfate	50	5
amyl acetate, n- (odor)	27	2.7
amyl acetate, sec- (odor)	11	1.1
amyl alcohol, n- (odor)	430	43
amyl amine, n-	150	15
amyl bromide	250	25
amyl hydroperoxide, t-	100	10
amyl mercaptan, n- (odor)	0.1	0.01
amyl methyl ether, n- (odor)	520	52
amyl methyl ether, t- (odor)	520	52
amyl peroxybenzoate, t-	15	1.5
amyl phenol, p-tert-, particulate	35	3.5
amyl phenol, p-tert-, vapor	700	70
amylene, alfa- (odor)	90	9
amylenes	22950	2295
aniline	76	8
anisidine, o-, p- isomers	5	0.5
anisole	100	10
anthracene*	0.5	0.05
anthraquinone, particulate	50	5
antimony (as Sb)	5	0.5
antimony trioxide	5	0.5
ANTU	3	0.3
apiole (odor)	57	5.7
Aramite	100	10
argon	simple asphyxiant	
Aromatic 100	1230	123
Aromatic 150	2560	256
Aromatic 200	4200	420
Aromatic Distillate, Heavy	2560	256
Aromatic Naphtha, Heavy	4200	420
Aromatic Solvent 104	1230	123
arsenic & inorganic cpds	0.1	0.01
arsenic pentoxide	0.1	0.01
arsenic, organic (as As)	5	0.5
arsine**	1.6	0.16
asbestos, all forms	0.03	0.003
asphalt, fumes* (cyclohexane extractable)	5	0.5
asphalt, vapours	350	35
Atrazine	50	5
Azaserine	8.8	0.88
azine (odor)	69	6.9
azinphos-methyl	2	0.2
azoxystrobin, particulate	50	5
Banvel (Herbicide)	100	10
barite, respirable	50	5
barium & compounds (as Ba)	5	0.5
barium sulfate, respirable	50	5
Bauxite	50	5
Baygon	5	0.5
Baytan	30	3
Baythroid, particulate	50	5
Beech wood dust	10	1
Benomyl (Fungicide), respirable	50	5
Bentonite	20	2
benzal chloride	20	2
benzaldehyde (odor)	22	2.2
benzene	75	3
benzene (24 hour)	12	3
benzene azimide	100	10
benzene raffinate	3500	350
benzenethiol dichloride	20	2
benzine	3500	350
benzo[a]pyrene*	0.03	0.003
benzo[b]fluoranthene	0.5	0.05
benzocyclobutyl pentanone, 1-	25	2.5
benzoic acid	50	5
benzoin isobutyl ether	100	10
benzonitrile	505	51
benzophenone	150	15
benzotriazole	100	10

Substance	Short-term ESL (μg/m^3)	Long-term ESL (μg/m^3)
benzotrichloride	8	0.8
benzoyl carbinol	3440	344
benzoyl chloride	60	6
benzoyl peroxide	50	5
benzyl acetate	610	61
benzyl alcohol	500	50
benzyl benzoate	590	59
benzyl carbinol	500	50
benzyl chloride	50	5
benzyl dichloride	20	2
benzyl dimethylamine	108	11
beryllium, particulate*	0.02	0.002
BHT	100	10
bicycloheptadiene	2000	200
Bifenox, particulate	50	5
Bifenthrin	25	2.5
biphenyl (odor)	2.3	0.23
biphenylyl phenyl ether	100	10
bis(2-chloroethyl)-2-naphthylamine	380	38
bis(2-chloroethyl)ether	290	29
bis(chloromethyl)ether**	0.047	0.0047
bismuth telluride, particulate, respirable	50	5
bismuth telluride, selenium-doped	50	5
bisphenol A, particulate	40	4
bisphenol A, vapor	800	80
black grit	50	5
Blazer, particulate	50	5
boiler slag	50	5
borates, tetrasodium salts: anhydrous	10	1
borates, tetrasodium salts: decahydrate	50	5
borates, tetrasodium salts: pentahydrate	10	1
boric acid*	10	1
boron	100	10
boron oxide, respirable	50	5
boron tribromide	100	10
boron trichloride**	5	0.5
boron trifluoride** (as HF, 3hr)	4.9	0.5
Botran 75W	100	10

Substance	Short-term ESL (μg/m^3)	Long-term ESL (μg/m^3)
Bromacil	100	10
brominated hydrocarbons	50	5
bromine pentafluoride (as HF, 3hr)	4.9	0.5
bromine**	6.6	0.66
bromo-3-chloropropane, 1-	0.5	0.05
bromobenzene	30	3
bromochloromethane	10600	1060
bromoethane	220	22
bromofluorobenzene	720	72
bromoform	52	5
Brucine	20	2
butadiene, 1,3-*	110	11
butane	19000	1900
butanediol	500	50
butanethiol (odor)	1.8	0.18
butanone (odor)	3900	390
butene, 1- (odor)	160	16
butene, 2- (odor)	1300	130
butoxyethanol	240	24
butoxyethyl acetate, 2-	310	31
butoxytriglycol	1000	100
butyl acetate, n- (odor)	1850	185
butyl acetate, sec-	9500	950
butyl acetate, tert- (odor)	19	1.9
butyl acrylate, n- (odor)	183	18.3
butyl alcohol, n-	760	76
butyl alcohol, sec-	3030	303
butyl alcohol, tert-	3030	303
butyl aniline	100	10
butyl benzene, all isomers	2740	274
butyl benzyl phthalate	50	5
butyl Carbitol	1060	106
butyl catechol, tert-	350	35
butyl Cellosolve	240	24
butyl Cellosolve acetate	310	31
butyl chloride, sec-	4400	440
butyl chloride, tert-	4400	440
butyl chromate, tert- (as CrO3)	0.1	0.01
butyl ether, all isomers (odor)	370	37
butyl formate	21000	2100
butyl glycidyl ether	300	30
butyl glycolate	270	27

Substance	Short-term ESL (µg/m^3)	Long-term ESL (µg/m^3)
butyl hydroperoxide, t-	35	3.5
butyl hydroquinone, t-	59	5.9
butyl isocyanate	9	0.9
butyl lactate	300	30
butyl mercaptan, n- (odor)	1.8	0.18
butyl methacrylate	6970	697
butyl peroxide, tert-	100	10
butyl peroxybenzoate, t-	15	1.5
butyl phenol, o-sec-	310	31
butyl phenol, o-tert-	20	2
butyl phenol, p-sec-	130	13
butyl phenol, p-tert-	5	0.5
butyl propionate, n-	230	23
butyl toluene diamine, t-	70	7
butyl toluene, p-tert-	61	6.1
butyl-6-ethylaniline, 2-sec-	100	10
butylacrylamide, tert-	2.6	0.26
butylamine, n-	150	15
butylamine, sec-	150	15
butylamine, tert-	12	1.2
butylated hydroxytoluene	100	10
butylene glycol, 1,2-	2100	210
butylene glycol, 1,3-	4400	440
butylene glycol, 1,4-	500	50
butylene glycol, 2,3-	1400	140
butylene oxide (odor)	206	20.6
butyl-m-xylene, tert-	3300	330
butynediol, 1,4-	200	20
butyraldehyde (odor)	14	1.4
butyric acid (odor)	18	1.8
butyric anhydride	250	25
butyrolactam, gamma-	140	14
butyrolactone, gamma-	2180	218
butyronitrile	220	22
Cacodylic acid (as As)	5	0.5
cadmium & compounds (as Cd)	0.1	0.01
calcium arsenate (as As)	0.1	0.01
calcium bromide	100	10
calcium carbonate, respirable	50	5
calcium chloride	70	7
calcium chromate (as Cr)	0.1	0.01
calcium cyanamide	5	0.5

Substance	Short-term ESL (µg/m^3)	Long-term ESL (µg/m^3)
calcium cyanide (as CN)	50	5
calcium hydroxide	50	5
calcium lignosulfate	50	5
calcium oxide	20	2
calcium phosphide	50	5
calcium silicate, respirable	50	5
calcium sulfonate	50	5
camphene	20	2
camphor, synthetic	20	2
capric acid (odor)	14	1.4
caproic acid (odor)	29	2.9
caprolactam, dust	10	1
caprolactam, vapor	230	23
caprolactone	2180	218
caprylic acid (odor)	48	4.8
Captafol	1	0.1
Captan	50	5
Carbanil	5	0.5
Carbaryl	50	5
carbazole	100	10
Carbitols	see diethylene glycol ethers	
Carbofuran	1	0.1
carbon black	35	3.5
carbon dioxide	90000	9000
carbon disulfide**	30	3
carbon monoxide	must meet NAAQS	
carbon tetrabromide	14	1.4
carbon tetrachloride	126	13
carbon tetrafluoride	18000	1800
carbon trifluoride	14300	1430
carbonyl chloride**	4	0.4
carbonyl fluoride (as HF, 3hr)	4.9	0.5
carbonyl sulfide	8	0.8
catechol	230	23
Cellosolve	180	18
cellulose acetate	100	10
cellulose acetate butyrate	100	10
cellulose acetate phthalate	100	10
cellulose acetate propionate	100	10
cellulose, respirable	50	5
ceric oxide	100	10
cesium hydroxide	20	2

Substance	Short-term ESL (µg/m^3)	Long-term ESL (µg/m^3)
cetyl mercaptan	53	5.3
chlodiphenyl, 42% chlorine	0.1	0.01
chlodiphenyl, 54% chlorine	0.1	0.01
chlordane	5	0.5
chlordecone	0.01	0.001
chlorinated camphene	5	0.5
chlorinated diphenyl oxide	5	0.5
chlorine dioxide**	2.8	0.3
chlorine trifluoride** (also evaluate HF)	1.9	0.19
chlorine**	15	1.5
chlorite (chlorine dioxide ion)	2.8	0.3
chloro-1,3-butadiene,** 2-	36	3.6
chloro-2,3-epoxypropane**	19	1.9
chloro-6-(trichloromethyl)-pyridine, 2-, respirable	50	5
chloroacetaldehyde	32	3
chloroacetic acid	12	1.2
chloroacetic acid methyl ester	50	5
chloroacetone	38	4
chloroacetophenone	3.2	0.32
chloroacetylchloride	2.3	0.23
chloroacetylene	3.9	0.39
1-(3-chloroallyl)-3,5,7-aza-1-azoniad adamantane chloride	5	0.5
Chloroambucil	5	0.5
chloroamphenicol	50	5
chloroaniline, m-	31	3.1
chloroaniline, o-	53	5.3
chloroaniline, p-	53	5.3
chlorobenzene	460	46
Chlorobenzilate	100	10
chlorobenzyl chloride	26	2.6
chlorobenzylidene malononitrile, o-	4	0.4
chlorobromomethane	10600	1060
chlorocresol (odor)	20	2
chlorodifluoroethane, 1,1,1-	61700	6170
chlorodifluoromethane	18000	1800
chlorodifluoromethane	18000	1800
chloroethane	500	50
chloroethanol, 2-	33	3.3
chloroethylene	130	13

Substance	Short-term ESL (µg/m^3)	Long-term ESL (µg/m^3)
chloroform**	98	9.8
chloroglycerin	50	5
chloroisopropyl ether, bis-	210	21
chloromethylmethyl ether**	0.5	0.05
Chloroneb, particulate	50	5
chloronitrobenzene, p-	6.4	0.64
chloronitropropane	100	10
chloropentafluoroethane	63200	6320
chlorophenol, m- (odor)	19	1.9
chlorophenol, o- (odor)	2	0.2
chlorophenol, p-	300	30
chlorophenolthiomethyl-O,O-diethyl phosphorodithioate	1	0.1
chlorophenolthio-methyl-O,O-diethyl phosphorodithioate	1	0.1
chlorophenyl phenyl ethers	5	0.5
1,1-bis-(chlorophenyl)-2,2,2,-trichloroethanol	10	1
chloropicrin	6.7	0.67
chloroprene,** ß-	36	3.6
chloropropionic acid, 2-	4.4	0.44
chloropropionitrile, 3-	180	18
chlorostyrene, o-	2850	285
chlorosulfonic acid	14	1.4
chlorotetrafluoroethane	27900	2790
Chlorothanonil	15	0.5
chlorotoluene, all isomers (odor)	235	23.5
chlorotrifluoroethylene	97	10
chlorotrifluoromethane	43300	4330
chlorotrifluoromethylphenoxytoluene	300	30
Chlorpyrifos	2	0.2
chromium (II) & (III) cpds	1	0.1
chromium (VI) cpds	0.1	0.01
chromium metal	1	0.1
chromium trioxide (CrO3)	0.1	0.01
chromium: chromic acid (H2CrO4) & chromate	0.1	0.01
chromyl chloride	0.1	0.01
chrysene*	0.5	0.05
citraconic anhydride	60	6
citric acid	100	10
Clopidol, respirable	50	5

Substance	Short-term ESL (μg/m^3)	Long-term ESL (μg/m^3)
coal dust: anthracite (also evaluate crystalline silica)	4	0.4
coal dust: bituminous (also evaluate crystalline silica)	9	0.9
coal tar	1	0.1
coal tar distillate	3500	350
coal tar naphtha	3500	350
coal tar oil	1	0.1
coal tar pitch volatiles, PAH<10% b(a)p	0.5	0.05
coating pigments, all non-metallic	40	4
cobalt & inorganic cpds	0.2	0.02
cobalt carbonyl, as Co	1	0.1
cobalt hydrocarbonyl	1	0.1
Cobra	50	5
coke oven emissions	1.5	0.15
coke oven emissions: total particulates	5	0.5
Combat	14	1.4
copper dusts & mists	10	1
copper fume	1	0.1
creosote	1	0.1
cresols (odor)	5	0.5
cresyl glycidyl ether	30	3
cresylic acid (odor)	5	0.5
cristobalite*	0.5	0.05
crotonaldehyde**	8.6	0.86
Cruformate	50	5
cumeme (odor)	500	50
cumene hydroperoxide	25	2.5
cumyl phenol, p-	140	14
cyanamide	20	2
cyanide compounds (as CN)	50	5
cyanogen	210	21
cyanogen bromide	2.5	0.25
cyanogen chloride**	6	0.6
Cycasin	40	4
cyclododecane	5150	515
cyclododecanone	1600	160
cyclododecatriene,1,5,9-	1320	132
cyclododecyl alcohol	9800	980
cycloheptane	3400	340
cyclohexane (odor)	1435	143.5

Substance	Short-term ESL (μg/m^3)	Long-term ESL (μg/m^3)
cyclohexanediamine	467	47
cyclohexanone (odor)	481	48.1
cyclohexene (odor)	604	60
cyclohexyl alcohol (odor)	613	61.3
cyclohexyl isocyanate	20	2
cyclohexyl-2-pyrrolidone	82	8.2
cyclohexylamine**	80	8
cyclohexylmercaptan	24	2.4
cyclonite	5	0.5
cyclooctadiene	2000	200
cyclooctane	3500	350
cyclopentadiene	2030	203
cyclopentane	3400	340
cyclopentanone	1700	170
cyclopentene	8150	815
cyclopentyl alcohol	7200	720
cyclotetramethylenetetranitramine	27	2.7
Cyfluthrin	50	5
Cyhexatin	50	5
cymene, p-	2745	275
cypermethrin	50	5
Cyromazine	100	10
2,4-D	10	1
Dalapon	58	5.8
Danitol	50	5
Daunomycin	1.4	0.14
DDT	1	0.1
deanol (odor)	55	5.5
decaborane	2.5	0.25
decabromodiphenyl oxide	50	5
decahydronaphthalene	3500	350
decalin	3500	350
decane	10000	1000
decanoic acid (odor)	14	1.4
decyl alcohol (odor)	39	3.9
decylmercaptan	36	3.6
Delnav	2	0.2
Demeton	1	0.1
demeton-methyl	5	0.5
Dextrin	100	10
di(2-ethylhexyl)adipate	1240	124
di(2-ethylhexyl)phthalate	50	5

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
diacetone alcohol (odor)	1330	133
diacetoxy-1-butene, 3,4-	8750	875
dialkyl peroxides, all	100	10
diallylamine	120	12
diaminodipropylamine, 3,3-	60	6
diaminoethane**, 1,2-	250	25
diatomaceous earth	40	4
Diazinon	1	0.1
diazomethane**	3.4	0.34
dibasic ester	100	10
dibenzo[b,e]pyridine	0.5	0.05
dibenzopyrrole	100	10
diborane**	1.1	0.11
dibrom	30	3
dibromoacetonitrile	33	3.3
dibromochloropropane	0.1	0.01
dibromoethane, 1,2-	3.8	0.38
dibutyl acrylate	550	55
dibutyl maleate	2600	260
dibutyl phenyl phosphate	35	3.5
dibutyl phosphate	86	8.6
dibutyl phthalate	50	5
dibutylamine, n- (odor)	65	6.5
dibutylaminoethanol, 2-N-	140	14
Dicamba	100	10
Dichlobenil, particulate	25	2.5
dichloro-1-butene, 3,4-	135	14
dichloro-1-nitroethane,1,1-	120	12
dichloro-2-butene, 1,3-	56	5.6
dichloro-2-butene, 1,4-	6	0.6
dichloro-4-nitroaniline, 2,6-	100	10
dichloro-4-nitroaniline, 2,6-	100	10
dichloroacetylene	3.9	0.39
dichloroaniline, 2,5-	210	21
dichloroaniline, 3,4-	80	8
dichlorobenzene, m-	2500	250
dichlorobenzene, o-	1500	150
dichlorobenzene, p-	600	60
dichlorobenzotrifluoride	890	89
dichlorobutylene	18	1.8
dichlorodifluoromethane	49500	4950
dichlorodimethylhydantoin	2	0.2
dichloroethane, 1,1-	4000	400

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
dichloroethane, 1,2-	160	4
dichloroethane, 1,2- (24-hour)	16	4
dichloroethyl ether	290	29
dichloroethylene, 1,1-	40	4
dichloroethylene, 1,2-	7930	793
dichlorofluoroethane	4350	435
dichlorofluoromethane	420	42
dichlorohydrin	130	13
dichloromethane	260	26
dichloromethoxybenzoic acid	100	10
dichloromethyl ether**	0.047	0.0047
dichloromethyl phosphine oxide	3	0.3
dichloronitrobenzene, all isomers	9	0.9
dichlorophenol, 2,4-	525	53
dichlorophenol, 2,6- (odor)	20	2
dichlorophenoxy acetic acid	10	1
2-(3,4-dichlorophenyl)-methyl-1,2,4-oxadiazolidine-3,5-dione	35	3.5
dichloropropane, 1,2- (odor)	1150	115
dichloropropene, 1,3-	45	4.5
dichloropropionanilide	15	1.5
dichloropropionic acid, 2,2-	58	5.8
dichlorosilane	3	0.3
dichlorotetrafluoroethane	69900	6990
dichlorotrifluoroethane	5500	550
Dichlorvos	9	0.9
Dicrotophos	2.5	0.25
dicyclohexylmethane-4,4'-diisocyanate	0.54	0.054
dicyclopentadiene (odor)	31	3.1
dicyclopentadienyl iron, respirable	50	5
Dieldrin	2.5	0.25
Dienochlor	8	0.8
diepoxybutane, 3,4-	5	0.5
diesel fuel (vapor) (MW= appr. 180)	1000	100
diesel fuel combustion products	1.5	0.15
diesel fuel combustion vapors	90	9
diethanolamine	20	2

Substance	Short-term ESL (µg/m^3)	Long-term ESL (µg/m^3)
diethyl ether (odor)	927	93
diethyl hydroxylamine	400	40
diethyl ketone	7050	705
diethyl phosphorochlorodithioate	70	7
diethyl phthalate	50	5
diethyl sulfate	25	2.5
diethyl sulfide (odor)	16	1.6
diethylamine	150	15
diethylaminoethanol, 2- (odor)	55	5.5
diethylaniline, N,N-	100	10
diethylbenzene	2500	250
diethylene glycol dimethyl ether	270	27
diethylene glycol divinyl ether	550	55
diethylene glycol ethyl ether	1500	150
diethylene glycol ethyl methyl ether	500	150
diethylene glycol ethyl vinyl ether	720	72
diethylene glycol mono-2-methyl pentyl ether	260	26
diethylene glycol monobutyl ether	1060	106
diethylene glycol monoisobutyl ether	1330	133
diethylene glycol monomethyl ether	270	27
diethylene glycol monovinyl ether	290	29
diethylene glycol, particulate	100	10
diethylene glycol, vapor	2200	220
diethylene triamine	42	4.2
diethylthiourea	50	5
difluorodibromomethane	8580	858
difluoroethane	13500	1350
difluoromethane	10630	1063
diglycidyl bisphenol A ether	14	1.4
diglycidyl ether	5.3	0.53
diglycolamine	380	38
dihydroxybenzene	20	2
dihydroxybenzene, 1,3	230	23
diisobutyl ketone (odor)	639	63.9
diisobutyl phthalate	50	5
diisobutylamine	125	13
diisobutylcarbinol (odor)	188	18.8
diisobutylene	1800	180
diisononyl phthalate, particulate	50	5
diisopropanolamine	460	46
diisopropylamine	210	21
diisopropylbenzene, all isomers	3320	332
diisopropylene glycol	100	10
dimeryl diisocyanate	0.25	0.025
dimethanonaphthalene	3.2	0.32
dimethoxyethane, 1,2-	220	22
dimethoxymethane	31100	3110
dimethxoybenzene, 1,2-	24	2.4
dimethyl acetamide	360	36
dimethyl adipate	100	10
dimethyl arsenic acid (as As)	5	0.5
dimethyl benzidine	0.2	0.02
dimethyl butane	3500	350
dimethyl ether	19100	1910
dimethyl ethyl amine, N,N-	750	75
dimethyl glutarate	100	10
dimethyl hexynediol	100	10
dimethyl hydrazine**, 1,1-	0.25	0.025
dimethyl oxazolidinone	2500	250
dimethyl propanolamine	750	75
dimethyl succinate	100	10
dimethyl sulfate	5.2	0.52
dimethyl sulfide (odor)	3	0.3
dimethyl sulfoxide	140	14
dimethyl terephthalate, respirable	50	5
dimethyl thionates	50	5
dimethyl zinc	10	1
dimethyl-1,2-dibromo-2,2-dichloroethyl phosphate	30	3
dimethyl-3-hydroxythiophene, 2,4-	100	10
dimethyl-4-heptanol, 2,6- (odor)	188	18.8
dimethyl-4-heptanone, 2,6- (odor)	639	63.9
dimethylamine (odor)	37	3.7
dimethylamino-2-propanol	750	75

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
dimethylaminobenzene	25	2.5
dimethylaminoethanol, 2- (odor)	55	5.5
dimethylaminoethoxyethanol	130	13
2-(2-(2-dimethylamino ethoxy)-ethylmethylamino)-ethanol	210	21
dimethylaminoethyl, ether, bis 2-	3.3	0.33
dimethylaminoethyl methacrylate	200	20
dimethylaminopropylamine	130	13
dimethylaminoxylylmethylcarbamate	5	0.5
dimethylaniline, N,N- (odor)	64	6.4
dimethylbenzene (odor)	3700	370
dimethylbenzylamine, N,N-	108	11
dimethylcarbamoyl chloride	0.5	0.05
dimethylcyclohexylamine, N,N-	100	10
dimethylethanolamine (odor)	55	5.5
dimethylethoxysilane	21	2.1
dimethylformamide	300	30
dimethylphenol	165	16.5
dimethylphosphorochloridothioate, O,O-	30	3
dimethylphthalate	50	5
dimethylpiperazine	430	43
dinitolmide	50	5
dinitrobenzene, all isomers	10	1
dinitro-o-cresol	2	0.2
dinitrophenol, 2,6-	3	0.3
dinitrotoluene, all isomers	1.5	0.15
dioctyl azelate	100	10
dioctyldiphenylamine	100	10
dioxane, 1,4-	900	90
dioxans, polychlorinated, dibenzo	use TCDD toxicity equivalents approach	
Dioxathion	2	0.2
dioxins,2,3,7,8-tetrachlorinated, dibenzo-*	---	$3X10^{-8}$
dioxolane, 1,3-	520	52
diphenyl ether (odor)	8	0.8
diphenylamine	100	10
diphenyldimethoxysilane	1000	100
diphenylethylene	50	5

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
diphenylmethane-4,4'-diisocyanate	0.51	0.051
dipropyl ether	2500	250
dipropyl ketone	2330	233
dipropylamine	200	20
dipropylene glycol	1200	120
dipropylene glycol dibenzoate	220	22
dipropylene glycol monoethyl ether	2190	219
dipropylene glycol monomethyl ether	3000	300
dipropylene triamine	60	6
Diquat dibromide monohydrate, respirable	1	0.1
Diquat dibromide, respirable	1	0.1
Diquat, respirable	1	0.1
disodium phosphate, particulate	50	5
Disulfiram	20	2
Disulfoton	1	0.1
di-tert-amyl phenol	700	70
di-tert-butyl peroxide	100	10
di-tert-butyl-p-cresol, 2,6-	100	10
ditridecyl phthalate	100	10
Diuron	100	10
divinyl benzene	530	53
DMAEE	3.3	0.33
dodecanoic acid (odor)	28	2.8
dodecenylsuccinic anhydride	40	4
dodecyl benzene sulfonic acid, particulate	100	10
dodecyl benzene sulfonic acid, vapor	1000	100
dodecyl mercaptan	41	4
dodecyl phenol	1200	120
dodecylamine	100	10
Dowfax 2A1	50	5
Dowtherm 4000 (46% ethylene glycol)	260	26
Dowtherm G	20	2
Dowtherm LF (mixture of phenyl ether, alkyl biphenyls)	13	1.3
Dripolene	3500	350
Dursban	2	0.2
Dylox, particulate	50	5

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
emery, respirable	50	5
Endosulfan	1	0.1
Endrin	1	0.1
enflurane	5660	566
enzymes	0.0006	0.00006
epichlorohydrin**	19	1.9
Epinephrine	0.4	0.04
EPN	5	0.5
Epoxide 7	800	80
Epoxide 8	800	80
epoxy resin	40	4
epoxy-1-propanol, 2,3-	61	6.1
epoxypropane**	210	21
erythromycin	30	3
ethane	simple asphyxiant	
ethanolamine	75	7.5
ethenylcyclohexene, 4-	4	0.4
Ethion	4	0.4
ethoxybenzene	130	13
ethoxyethanol acetate, 2-	270	27
ethoxyethanol, 2-	180	18
ethoxypropionitrile, ß-	2000	200
ethoxytriglycol	160	16
ethyl acetate	14400	1440
ethyl acrolein	60	6
ethyl acrylate (odor)	5	0.5
ethyl alcohol	18800	1880
ethyl amyl ketone	1310	131
ethyl aniline	20	2
ethyl benzene (odor)	2000	200
ethyl benzene hydroperoxide	4350	435
ethyl benzoate	245	25
ethyl bromide	220	22
ethyl butyl ketone	2340	234
ethyl butyrate (odor)	39	3.9
ethyl Carbitol	1500	150
ethyl chloride	500	50
ethyl chlorocarbonate	5	0.5
ethyl cyanide**	140	14
ethyl ether (odor)	927	93
ethyl formate	3000	300
ethyl hexane	3500	350
ethyl hexanediol, 2-	500	50

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
ethyl mercaptan** (odor)	0.8	0.08
ethyl methacrylate (odor)	32	3.2
ethyl morpholine, N-	240	24
ethyl propionate	130	13
ethyl silicate	850	85
ethyl sulfide (odor)	16	1.6
ethyl thioacetate	75	7.5
ethyl trichloroacetate	70	7
ethyl-2-methylallylamine	50	5
ethyl-3-ethoxypropionate	400	40
ethyl-3-propyl acrolein	150	15
ethylamine	92	9.2
ethylanthraquinone	50	5
ethylcyanoacrylate	10	1
ethylcyclohexane	18670	1867
ethylcyclopentane	16300	1630
ethylene	1170	---
ethylene amine	200	20
ethylene bisdithiocarbamates	50	5
ethylene chlorohydrin	33	3.3
ethylene cyanide	200	20
ethylene cyanohydrin	50	5
ethylene dibromide	3.8	0.38
ethylene dichloride	160	4
ethylene dichloride (24 hour)	16	4
ethylene glycol butyl ethyl ether	185	19
ethylene glycol butyl vinyl ether	940	94
ethylene glycol carbonate	100	10
ethylene glycol diacetate (odor)	555	55.5
ethylene glycol diallyl ether	90	9
ethylene glycol dibutyl ether	1500	150
ethylene glycol diethyl ether	350	35
ethylene glycol dimethyl ether	220	22
ethylene glycol dinitrate	1	0.1
ethylene glycol mono-2-methylpentyl ether	110	11
ethylene glycol monobenzyl ether	100	10
ethylene glycol monobutyl ether	240	24
ethylene glycol monobutyl	310	31

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
ether acetate		
ethylene glycol monoethyl ether	180	18
ethylene glycol monoethyl ether acetate	270	27
ethylene glycol monohexyl ether	420	42
ethylene glycol monoisobutyl ether	770	77
ethylene glycol monoisopropyl ether	220	22
ethylene glycol monomethyl ether	160	16
ethylene glycol monomethyl ether acetate	240	24
ethylene glycol monophenyl ether	170	17
ethylene glycol monopropyl ether	1500	150
ethylene glycol mono-sec-butyl ether	360	36
ethylene glycol, vapor	260	26
ethylene naphthalene*	1	0.1
ethylene oxide**	18	1.8
ethylene thiourea	50	5
ethylenediamine**	250	25
ethyl lactate	1930	193
ethyleneimine**	8.8	0.88
ethylhexanoic acid, 2-	250	25
ethylhexyl alcohol, 2- (odor)	735	73.5
ethylhexyl aldehyde	1400	140
ethylhexyl chloride, 2-	2500	250
ethylhexyl nitrate	1050	105
ethylidene chloride	4000	400
ethylidene-2-norbornene, 5- (odor)	70	7
ethyl-n-butyl ether	2340	234
ethylpentane, 3-	3500	350
ethyl-t-butyl ether	2500	250
ethyltoluene, m-	1250	125
ethyltoluene, o-	1250	125
ethyltoluene, p-	1250	125
Exxate 600	2750	275
famotidine	50	5
Famphur	13	1.3
fatty acids	1000	100

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
fatty amines	100	10
fatty oils	1000	100
Fenamiphos	1	0.1
Fenpropathrin	50	5
Fensulfothion	1	0.1
Fenthion	2	0.2
Fenvalerate	50	5
Ferbam, respirable	50	5
ferrovanadium dust	10	1
fibrous glass dust	50	5
fluorene	10	1
fluorides & HF (as HF, 3hr)	4.9	0.5
fluorine**	2	0.2
fluorobenzene	390	39
fluoromethane	6960	696
fluorotrichloromethane (odor)	28000	2800
fluroxene	103	10
Fonophos	1	0.1
formaldehyde**	15	1.5
formalin** (37-50% formaldehyde)	30	3
formamide	180	18
formic acid	94	9.4
formic acid, ethyl ester	3000	300
formic acid, methyl ester	2500	250
Freon 11(odor)	28000	2800
Freon 112	41700	4170
Freon 113	38000	3800
Freon 114	69900	6990
Freon 116	28200	2820
Freon 12	49500	4950
Freon 123	5500	550
Freon 125	24540	2454
Freon 12B2	8580	858
Freon 13B1	61000	6100
Freon 14	18000	1800
Freon 141b	4350	435
Freon 142b	61700	6170
Freon 143a	17140	1714
Freon 152A	13500	1350
Freon 21	420	42
Freon 22	18000	1800
Freon 23	14300	1430

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
Freon 32	10630	1063
Freon 41	6960	696
Freon TE	68300	6830
Freon TF	38000	3800
Freon TMS	28300	2830
fuel oils	1000	100
furan**	280	28
furanone	600	60
furans, chlorinated, dibenzo-	use TCDD toxicity equivalents approach	
furatone	50	5
furfural	79	8
furfuryl alcohol	400	40
gallium arsenide (as As)	0.1	0.01
Garlon 3A	40	4
gasoline additives, mist	50	5
gasoline additives, vapor	3000	300
gasoline, < 0.9% benzene	3500	350
germanium tetrahydride	6.3	0.63
glutaraldehyde	2	0.2
glycerin mist, respirable	50	5
glycidol	61	6.1
glycidyl ether, C10	800	80
glycolonitrile	50	5
glyoxal	70	7
glyoxylic acid	75	7.5
Glyphosate	50	5
grain dust, total (oats, wheat, barley)	40	4
graphite, natural, respirable	20	2
graphite, synthetic, respirable	20	2
guaifenesin	100	10
guthion	2	0.2
gylcidyl methacrylate	580	58
gypsum, respirable	50	5
hafnium	5	0.5
HALAR not containing NiO	40	4
halothane	162	16
HCFC-124	27900	2790
helium	simple asphyxiant	
hemimellitene	1250	125
Heptachlor	0.5	0.05
Heptachlor epoxide	0.5	0.05
heptal chloride, n- (odor)	60	6

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
heptane	3500	350
heptanoic acid (odor)	108	10.8
heptanone, 2- (odor)	94	9.4
heptanone, 3-	2340	234
heptene (odor)	16	1.6
heptyl alcohol (odor)	1900	190
heptyl aldehyde (odor)	240	24
heptylmercaptan (odor)	1	0.1
hexachlorobenzene	0.25	0.025
hexachlorobutadiene	2.1	0.21
hexachlorobutene	24	2.4
hexachlorocyclohexane, gamma-	5	0.5
hexachlorocyclopentadiene	1.1	0.11
hexachloroethane	97	9.7
hexachloronaphthalene	2	0.2
hexachloropropene	60	6
hexadecyl mercaptan	53	5.3
hexadiene (odor)	1675	167.5
hexafluoroacetone	7	0.7
hexafluoroethane	28200	2820
hexafluoroisobutylene	34	3
hexamethyl disilizane	200	20
hexamethylene diamine (odor)	3.2	0.32
hexamethylene diisocyanate	0.34	0.034
hexamethylene diisocyanate polymer	4	0.4
hexamethylene glycol	750	75
hexamethyleneimine	100	10
hexamethylenetetramine	170	17
hexane, n-	1760	176
hexane, other isomers	3500	350
hexanediamine, 1,6- (odor)	3.2	0.32
hexanitrostilbene	20	1
hexanoic acid (odor)	29	2.9
hexanone, 2-	40	4
Hexazinone	50	5
hexene (odor)	70	7
hexone	2050	205
hexyl acetate, sec- (odor)	412	41.2
hexyl alcohol (odor)	42	4.4
hexyl bromide	135	14
hexyl mercaptan	27	2.7

Substance	Short-term ESL (μg/m^3)	Long-term ESL (μg/m^3)
hexylene glycol	1210	121
HFC-134A	20860	2086
HFC-245fa	27400	2740
HFC-365mfc	30260	3026
hydramethylnon	14	1.4
hydraulic oil	1000	100
hydrazine**	0.13	0.013
hydrazoic acid (N3H)	1.8	0.18
hydrogen	simple asphyxiant	
hydrogen bromide**	99	10
hydrogen chloride*,**	75	0.1
hydrogen cyanide**	50	5
hydrogen fluoride** (3hr)	4.9	0.5
hydrogen iodide	150	15
hydrogen peroxide	14	1.4
hydrogen selenide**	1.6	0.16
hydrogen sulfide**	TNRCC Reg II	
hydrogenated terphenyls	50	5
hydroquinone	20	2
hydroquinone monomethyl ether	50	5
1-(2-hydroxyethyl)-2-(tall oil-alkyl)-2-imidazoline	50	5
4-hydroxy-4-methyl-2-pentanone (odor)	1330	133
hydroxy-2-phenyl acetophenone	3440	344
hydroxyacetophenone oxime, 4-	1250	125
hydroxyacetophenone, 2-	1250	125
hydroxyacetophenone, 4-	2500	250
hydroxyanisole, p-	50	5
hydroxyethyl acrylate, 2-	50	5
hydroxyethyl ethylenediamine	640	64
hydroxyethyl methacrylate, 2-	3170	317
hydroxyethylethylene urea	100	10
hydroxylamine	22	2.2
hydroxymethyl amino-nitrofurylethenyltriazine	50	5
hydroxypivaldehyde	1800	180
hydroxypivalyl hydroxypivalate, particulate	50	5
hydroxypropyl acrylate, 2-	28	2.8
hydroxypropyl methacrylate	90	9

Substance	Short-term ESL (μg/m^3)	Long-term ESL (μg/m^3)
hydroxyquinone	20	2
IBIB	3000	300
Ibuprofen	40	4
Imidacloprid	33	3.3
iminobispropylamine, 3,3'-	60	6
indene (odor)	71	7.1
indium & compounds (as In)	1	0.1
iodine	10	1
iodoform (odor)	6	0.6
iodopropynyl butyl carbamate	100	10
Iprodione	50	5
Irganox	100	10
iron oxide (fume)	50	5
iron pentacarbonyl** (as Fe)	8	0.8
iron salts, soluble	10	1
isatoic anhydride	100	10
isoamyl acetate (odor)	133	13.3
isoamyl alcohol (odor)	151	15
isoamyl ketone	1000	100
isoamylene, a- or ß- (odor)	715	72
isobutane (odor)	4845	484.5
isobutanolamine	400	40
isobutene (odor)	1403	140
isobutyl acetate (odor)	630	63
isobutyl acrylate (odor)	11	
isobutyl alcohol	1520	152
isobutyl heptyl ketone	3750	375
isobutyl isobutyrate	3000	300
isobutyl methacrylate	1900	190
isobutylamine	150	15
isobutyraldehyde (odor)	138	13.8
isobutyric acid (odor)	3.6	0.36
isobutyronitrile**	220	22
isocyanobenzotrifluoride	0.38	0.038
isodecyl acrylate	550	55
isodecyl methacrylate	8000	800
Isodrin	3.2	0.32
isoheptane	3070	307
isoheptyl alcohol	2700	270
isohexane (odor)	289	28.9
isononyl alcohol	2700	270
isooctane	3500	350

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
isooctyl alcohol	2660	266
isooctyl thioglycolate	30	3
Isopar C,E		
Isopar G,H,K,L,M		
isopentane	3500	350
isopentanoic acid (odor)	11	1.1
isopentyl nitrite	100	10
isophorone	230	23
isophorone diisocyanate**	0.45	0.045
isoprene (odor)	14	1.4
isopropanolamine	200	20
isopropanolamine dodecylbenzene sulfonate	20	2
isopropoxyethanol	220	22
isopropyl acetate (odor)	3755	375.5
isopropyl alcohol (odor)	7856	785
isopropyl benzene (odor)	500	50
isopropyl chloride	15000	1500
isopropyl ether (odor)	71	7.1
isopropyl glycidyl ether	2380	238
isopropyl methylthionocarbamate	100	10
isopropyl phenol	190	19
isopropyl pyridine	150	15
isopropylamine	120	12
isopropylaniline	110	11
isovaleraldehyde	1800	180
isovaleric acid (odor)	11	1.1
Jeffamine D-230	180	18
Jeffamine ED-600	500	50
jet fuel	1000	100
kaolin, respirable	20	2
Kelthane	10	1
Kepone	0.01	0.001
kerosene	1000	100
ketene	9	0.9
Kleen ATMS	10000	1000
lactic acid	50	5
Lactofen	50	5
lactol spirits	3500	350
lactose	100	10
Laktane	3500	350
lanthanum oxide	50	5
Lasiocarpine	29	2.9
latex	100	10
lauric acid (odor)	28	2.8
lauryl amine	100	10
lauryl mercaptan	41	4
lead	must meet NAAQS	
lead arsenate (as As)	0.1	0.01
lead chromate (as Cr)	0.1	0.01
Ligroine	3500	350
limestone, respirable	50	5
Lindane	5	0.5
Linuron	40	4
liquid detergent	50	5
liquid plastic	50	5
liquid resins	50	5
liquified petroleum gas	18000	1800
lithium hydride	0.25	0.025
lithium hydroxide	10	1
lithium oxide	10	1
lube oil and additives	1000	100
Lupersols	100	10
magnesite, respirable	50	5
magnesium chloride	100	10
magnesium oxide (fume), respirable	50	5
Malathion	50	5
maleic acid	14	1.4
maleic anhydride	10	1
maleic hydrazide	1000	100
malononitrile	80	8
maneb	2	0.2
manganese cyclopentadienyl tricarbonyl	1	0.1
manganese dust & inorganic compounds	2	0.2
manganese fume	2	0.2
marble, respirable	50	5
Melphalan	0.2	0.02
menthane-1,8-diamine, p-	20	2
MAPP	16400	1640
Mepiquat chloride, particulate	50	5
mercaptobenzothiazole	35	3.5
mercury aryl compounds	1	0.1
mercury metal & inorganic	0.25	0.025

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
forms		
mercury, alkyls	0.1	0.01
mercury, vapor	0.25	0.025
mesityl oxide (odor)	204	20.4
mesitylene	1250	125
Metalaxyl	50	5
methacrolein	3.7	0.37
methacrylamide	10	1
methacrylic acid	700	70
methacrylonitrile**	27	2.7
methacryloxyethyl ethylene urea	100	10
methane	simple asphyxiant	
methanesulfonic acid	100	10
methanethiol** (odor)	2	0.2
methapyrilene	38	3.8
Methomyl	25	2.5
methoxy-1-propanol, 2-	188	18.8
methoxybenzene	100	10
Methoxychlor, respirable	50	5
methoxyethane, 1,2-	220	22
methoxyethanol acetate, 2-	240	24
methoxyethanol, 2-	160	16
methoxyethyl acetate, 2-	240	24
methoxyflurane	135	13.5
methoxyphenol, 4-	50	5
methoxypropionitrile, 3-	2000	200
methoxy-1-propyl acetate, 2-	275	27.5
methoxypropylamine, 3-	370	37
methyl 2-cyanoacrylate	91	9.1
methyl acetate	6060	606
methyl acetoacetate	3000	300
methyl acetylene	16400	1640
methyl acetylene-propadiene mixture	16400	1640
methyl acrylate (odor)	58	5.8
methyl alcohol	2620	262
methyl amyl acetate (odor)	412	41.2
methyl amyl alcohol (odor)	292	29.2
methyl amyl ether, n- (odor)	520	52
methyl amyl ether, tert- (odor)	520	52
methyl amyl ketone (odor)	94	9.4
methyl aniline	22	2.2

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
methyl benzoate	160	16
methyl bromide**	117	12
methyl butyraldehyde	1800	180
methyl butyrate (odor)	8.5	0.9
methyl Cellosolve	160	16
methyl chloride	1030	103
methyl chloroform	10800	1080
methyl chloroformate**	2	0.2
methyl cumene, p-	2745	275
methyl cyclohexane	16100	1610
methyl cyclohexanol	2340	234
methyl cyclohexanone, o-	2290	229
methyl cyclohexene	940	94
methyl cyclopentadienyl manganese tricarbonyl (as Mn)	2	0.2
methyl cyclopentane	2580	258
methyl demeton	5	0.5
methyl dichlorosilane	7.5	0.75
methyl diethanolamine	500	50
methyl disulfide (odor)	22	2.2
methyl ethanolamine	140	14
methyl ether	19100	1910
methyl ethyl aniline	100	10
methyl ethyl benzene, all isomers	1250	125
methyl ethyl ketone (odor)	3900	390
methyl ethyl ketone peroxide	15	1.5
methyl formamide	110	11
methyl formate	2500	250
methyl furan, 2-	550	55
methyl glutaronitrile	84	8.4
methyl heptane	3500	350
methyl hexane, 2-	3070	307
methyl hexyl ketone	5100	510
methyl hydrazine**	0.19	0.019
methyl indenes	470	47
methyl iodide	120	12
methyl isoamyl ketone (odor)	56	5.6
methyl isobutyl carbinol (odor)	292	29.2
methyl isobutyl ketone	2050	205
methyl isobutyrate	100	10
methyl isocyanate**	0.47	0.047

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
methyl isopropyl ketone	7050	705
methyl isopropylbenzene, 4-	2745	275
methyl isothiocyanate	1	0.1
methyl mercaptan** (odor)	2	0.2
methyl methacrylate (odor)	339	33.9
methyl morpholine	350	35
methyl mustard oil	1	0.1
methyl naphthalenes, a-* [odor]	58	5.8
methyl naphthalenes, ß-* (odor)	58	5.8
methyl n-butyl ketone	40	4
Methyl parathion	2	0.2
methyl pentane, 2- (odor)	289	28.9
methyl pentane, 3-	3500	350
methyl phenyl ether	100	10
methyl phosphonic dichloride	3	0.3
methyl propionate	367	37
methyl propyl ketone	5300	530
methyl pyrrolidine, N-	70	7
methyl silicate	60	6
methyl styrene, a-	250	25
methyl sulfide (odor)	3	0.3
methyl t-butyl ether* (odor)	450	45
methyl trichlorosilane**	14	1.4
methyl vinyl ketone	6	0.6
methyl-2-pentanol, 4- (odor)	292	29.2
methyl-2-propenenitrile**, 2-	27	2.7
methyl-2-pyrrolidone, N-	800	80
methyl-3-heptanone, 5-	1310	131
methyl-3-methoxy proprionate	140	14
methyl-5-ethylpyridine, 2- (odor)	4	0.4
methylacrylonitrile**	27	2.7
methylal	31100	3110
methylamine**	64	6.4
methylaziridine**	50	5
methylbenzyl alcohol	600	60
methylbutyl acetate, 3- (odor)	27	2.7
methylene bis(2-chloroaniline)	1.1	0.11
methylene bis(4,4'-cyclohexylamine)	100	10
methylene bis(4-cyclohexylisocyanate)	0.54	0.054
methylene bisphenyl diioscyanate	0.51	0.051
methylene bisphenyl diioscyanate, polymer	3	0.3
methylene bromide	1320	132
methylene chloride	260	26
methylene chlorobromide	10600	1060
methylene dianiline, 4,4'-	8.1	0.81
methylimidazole, 1-	100	10
methylimidazole, 2-	100	10
methylimidazole, 4-	50	5
methylmaleic anhydride	60	6
methyloctanal, 2-	1500	150
methylstyrylphenol, p-	140	14
Metolachlor	100	10
Metribuzin	50	5
Mevinphos	0.92	0.092
mica	30	3
milk sugar	100	10
mineral oil mist	50	5
mineral spirits	3500	350
mineral wool fibers	50	5
molasses	100	10
molybdenum soluble	50	5
molybdenum insoluble	100	10
monochlorohydrin	50	5
Monocrotophos	2.5	0.25
morpholine (odor)	36	3.6
N-(2-hydroxyethyl)-1,2-diaminoethane	50	5
Naled	30	3
naphtha, coal tar	3500	350
naphtha, VM&P	3500	350
naphthalene (odor)	440	44
naphthalene diisocyanate	0.4	0.04
naphthalene diisocyanate, 1,5-	0.9	0.09
naphthenic acid	16000	1600
naphthoquinone, 1,4-	1	0.1
naphthylthiourea, a-	3	0.3
naphthylthiourea, beta-	3	0.3
natural gas condensate	18000	1800
Neodol	2700	270

Substance	Short-term ESL (μg/m^3)	Long-term ESL (μg/m^3)
neohexane	3500	350
neon	simple asphyxiant	
neopentyl glycol	500	50
nickel carbonyl**	0.15	0.015
nickel oxide	0.15	0.015
nickel sulfide	0.15	0.015
nickel sulfide roasting, fume & dust	0.15	0.015
nickel, metal & insoluble cpds	0.15	0.015
nickel, soluble compounds	0.15	0.015
nicotine	5	0.5
Nitrapyrin, respirable	50	5
nitric acid**	52	5.2
nitric oxide**	310	31
nitrilotriacetic acid	10	1
nitroaniline, p-	30	3
nitrobenzene	24	2.4
nitrochlorobenzene, p-	6.4	0.64
nitroethane	3070	307
nitroethanol	3100	310
nitrogen dioxide**	must meet NAAQS	
nitrogen trifluoride	290	29
nitroglycerin	1	0.1
nitromethane	500	50
nitrophenol, m-	40	4
nitrophenol, o-	40	4
nitrophenol, p-	10	1
nitropropane, 1-	910	91
nitropropane, 2-	50	5
nitrosoguanidine	30	3
nitrosomethylvinylamine	8	0.8
nitrosomorpholine, N-	140	14
nitrotoluene, m-	110	11
nitrotoluene, o-	110	11
nitrotoluene, p-	110	11
nitrotrichloromethane	6.7	0.67
nitrous oxide	900	90
nonane	10500	1050
nonene (odor)	26	2.6
nonoic acid (odor)	4.6	0.46
nonyl aldehyde	1500	150
nonyl phenol ethoxylate	600	60
nonyl phenol propoxylate	600	60

Substance	Short-term ESL (μg/m^3)	Long-term ESL (μg/m^3)
nonylmercaptan, n-	33	3.3
nonylphenol, mixed isomers	400	40
nonylphenyl polyethyleneglycol ether, nonionic	600	60
Norflurazon	100	10
Norpar 12, 13, 15		
octachloronaphthalene	1	0.1
octadecenylamine	310	31
octadecyl mercaptan	60	6
octadecyl-3,5-di-tert-butyl-4-hydroxyhydrocinnamate	100	10
octadiene, 1,7-	300	30
octane	3500	350
octanoic acid (odor)	48	4.8
octanone, 2-	5100	510
octene, 1- (odor)	20	2
octyl alcohol, 1- (odor)	11	1.1
octyl alcohol, 2- (odor)	13	1.3
octyl amine	60	6
octyl epoxy tallate	1000	100
octyl mercaptan	30	3
octyl phenol	20	2
octyl pyrrolidone, N-	100	10
oil mist, mildly refined containing PAHs	2	0.2
oil mist, mineral, severely refined	50	5
oil, crude (vapor)	3500	350
oil, hydraulic	1000	100
oil, lube (vapor)	1000	100
oils (misc., particulate)	100	10
oils (misc., vapor)	1000	100
oils, fuel	1000	100
oleic acid	100	10
oleic diethanol amide	20	2
Orthene	70	7
osmium tetroxide	0.016	0.0016
Ovasyn	35	3.5
oxalic acid	10	1
Oxinol	4570	457
oxo-hexyl acetate	2750	275
oxybis(N,N-dimethylethylamine)	3.3	0.33
Oxyfluorfen	16	1.6

Substance	Short-term ESL (µg/m³)	Long-term ESL (µg/m³)
oxygen difluoride** (also evaluate HF)	0.55	0.055
oxylated glycol ester	190	19
ozone**	must meet NAAQS	
paraffin oil	50	5
paraffin wax fume	20	2
paraformaldehyde	60	6
paraldehyde	440	44
Paraquat	1	0.1
Parathion	0.5	0.05
parrafinic distillate	50	5
pelargonic acid (odor)	4.6	0.46
Pendimethalin	100	10
pentaborane**	0.13	0.013
pentachlorobenzenes	1000	100
pentachloroethane	400	40
pentachloronaphthalene	5	0.5
pentachloronitrobenzene	5	0.5
pentachlorophenol	5	0.5
pentachloropyridine	80	8
pentadiene, 1,3-	1800	180
pentadiene, all isomers	1800	180
pentaerthryitol tetranitrate	50	5
pentaerthyritol triacrylate	10	1
pentaerythritol, respirable	50	5
pentaethylene hexamine	625	62.5
pentafluorobutane	30260	3026
pentafluoroethane	24540	2454
pentafluoropropane	27400	2740
pentamethylene diamine	200	20
pentane	3500	350
pentanedione (odor)	41	4
pentanone, 2-	5300	530
pentene nitrile, 3-	70	7
pentene, all isomers (odor)	90	9
pentylmercaptan (odor)	0.1	0.01
perchloroethylene	340	34
perchloromethyl mercaptan**	7.5	0.8
perchloryl fluoride** (as HF, 3 hr)	4.9	0.5
perfluoro compounds	200	20
perfluoroethane	28200	2820
perfluoroisobutylene	0.82	0.082

Substance	Short-term ESL (µg/m³)	Long-term ESL (µg/m³)
perlite, respirable	50	5
Permethrin	50	5
peroxydisulfuric acid	10	1
persulfates, particulate	10	1
petroleum coke, calcined	100	10
petroleum coke, uncalcined (green) if PAH content is < 10,000 ppm	50	5
petroleum distillates	3500	350
petroleum ether	3500	350
petroleum jelly	100	10
petroleum oil (vapor)	3500	350
petroleum spirits	3500	350
petroleum wax	100	10
phenacyl chloride	3.2	0.32
phenanthrene	0.5	0.05
phenetidine, p-	150	15
phenetole	130	13
phenol (odor)	154	15.4
phenol/formaldehyde resin	28	3
phenothiazine	50	5
phenyl ether (odor)	8	0.8
phenyl ethyl alcohol	500	50
phenylethylene (odor)	110	11
phenyl ethyl ether	130	13
phenyl glycidyl ether	60	6
phenyl hydrazine	4.4	0.44
phenyl isocyanate	5	0.5
phenyl isothiocyanate	0.5	0.05
phenyl mercaptan (odor)	4	0.4
phenyl methyl acetate	600	60
phenylene diamine, m-	1	0.1
phenylene diamine, o-	1	0.1
phenylene diamine, p-	1	0.1
phenylethylene (odor)	215	21.5
phenylphosphine	2.3	0.23
phenylpropyl alcohol	1100	110
phenylthiourea	4	0.4
Phorate	0.5	0.05
Phosdrin	0.92	0.092
phosgene**	4	0.4
Phosmet	20	2
phosphine**	4.2	0.42
phosphoric acid	10	1

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
phosphoric fertilizer	50	5
phosphorodithioic acid ester, zinc salt	1500	150
phosphorous acid	10	1
phosphorus (yellow)	1	0.1
phosphorus oxychloride**	6.3	0.63
phosphorus pentasulfide	10	1
phosphorus pentoxide	10	1
phosphorus trichloride**	11	1.1
phthalate ester	50	5
phthalic acid	60	6
phthalic anhydride, particulate	10	1
phthalodinitrile, m-	50	5
Picloram, respirable	50	5
picoline, 3-	80	8
picoline, 4-	46	4.6
picric acid (odor)	0.5	0.05
Pindone	1	0.1
pinene, a-	64	6.4
piperazine	35	3.5
piperazine dihydrochloride	50	5
piperidine**	36	3.6
piperylene	1800	180
pivalic acid	250	25
pivaloyl chloride	40	4
pivaloyl-1,3-indaione, 2-	1	0.1
Plaster of Paris, respirable	50	5
plastic dust	50	5
platinum, metal	10	1
platinum, soluble salts	0.02	0.002
poly(1-vinyl-2-pyrrolidinone)	100	10
polybutenes	5000	500
polychlorinated biphenyls	0.1	0.01
polycyclic aromatic HC's, particulate, <10% b(a)p, not otherwise classified*	0.5	0.05
polyethylene	100	10
polyethylene glycol 450 nonyl phenyl ether, nonionic surfactant	600	60
polyethylene glycol monooleate	200	20
polyethylene glycols (particulate)	100	10

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
polyethylene glycols (vapor)	1000	100
polyisobutyleneamine	770	77
polyisobutylenes	5000	500
polymeric hexamethylene diisocyanate	4	0.4
polymethylene polyphenylisocyanate	3	0.3
polyoxyethylene sorbitol ether	100	10
polypropylene	50	5
polypropylene glycol	100	10
polypropylene glycol, vapor	1000	100
polysaccharides	100	10
polystyrene	100	10
polyurethane	20	2
polyvinyl chloride	50	5
Portland cement, respirable	50	5
potassium	20	2
potassium bromate	1	0.1
potassium carbonate	50	5
potassium hydroxide	20	2
potassium permanganate	20	2
potassium persulfate, particulate	10	1
PPG-884	50	5
Primen	38	3.8
Probe	35	3.5
propane	18000	1800
Propanil	15	1.5
propargyl alcohol	23	2.3
Propazine	100	10
Propiconazole	65	7
propiolactone, ß-	15	1.5
propionaldehyde (odor)	21	2.1
propionic acid (odor)	103	10.3
propionic anhydride	250	25
propionitrile**	140	14
propiophenone	190	19
Propoxur	5	0.5
propoxyethanol	1500	150
propyl acetate (odor)	626	62.6
propyl acrylate (odor)	50	5
propyl alcohol	4920	492
propyl amines	120	12

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
propyl bromide	8000	800
propyl chloride	30000	3000
propyl ether	2500	250
propyl formate	6475	648
propyl mercaptan, n- (odor)	2.3	0.23
propyl nitrate	1070	107
propyl propasol	1280	128
propyl propionate	4750	475
propylene	117000	---
propylene carbonate, particulate	100	10
propylene carbonate, vapor	500	50
propylene chlorohydrin	170	17
propylene diamine (odor)	42	4.2
propylene dichloride (odor)	1150	115
propylene glycol allyl ether	330	33
propylene glycol dinitrate	3	0.3
propylene glycol isobutyl ether	2500	250
propylene glycol isopropyl ether	2600	260
propylene glycol-2-methyl ether	188	18.8
propylene glycol-2-methyl ether acetate	275	27.5
propylene glycol monoethyl ether	3830	383
propylene glycol monomethyl ether	3690	369
propylene glycol monomethyl ether acetate	2750	275
propylene glycol mono-n-butyl ether	730	73
propylene glycol monopropyl ether	1280	128
propylene glycol mono-t-butyl ether	730	73
propylene glycol phenyl ether	1860	186
propylene glycol, particulate	20	2
propylene glycol, vapor	1560	156
propylene imine**	47	4.7
propylene oxide**	210	21
propyne	16400	1640
pseudocumene	1250	125
PVC	50	5
pyrene*	0.5	0.05

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
Pyrethrum	50	5
pyridine (odor)	69	6.9
pyridines, alkyl	150	15
pyrocatechol	230	23
pyromelletic acid	2.5	0.25
pyromelletic dianhydride	2.5	0.25
pyronaphtha	40	4
pyrrole	21	2.1
pyrrolidine, 2-	70	7
pyrrolidone, 2-	140	14
quartz*	1	0.1
quinoline	5	0.5
quinone	4	0.4
RDX	5	0.5
reformate (reformed naphtha)	2000	200
Reserpine	7	0.7
resinol	190	19
resorcinol	450	45
rhodium, metal & insoluble cpds	1	0.1
rhodium, soluble cpds	0.01	0.001
Ronnel	100	10
rosin core solder, decomposition products	1	0.1
Rotenone	50	5
rouge, respirable	50	5
Roundup herbicide	50	5
rubber dust	50	5
rubber solvent	3500	350
rubidium	25	2.5
Saccharine	50	5
safrole	350	35
SC-100	1250	125
SC-150	1250	125
selenious acid, as Se	2	0.2
selenium & compounds	2	0.2
selenium hexafluoride**, (as Se, also evaluate total HF)	1.6	0.16
selenium oxide	2	0.2
Sesone, respirable	50	5
Sevin	50	5
silane	70	7
silica-amorphos: gel & precipitated silica	40	4

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
silica-amorphos: silica fume, respirable	20	2
silica-amorphos: silica fused	0.5	0.05
silica-amorphous: diatomaceous earth	40	4
silica-crystalline: cristobalite, respirable*	0.5	0.05
silica-crystalline: quartz, respirable*	1	0.1
silica-crystalline: tridymite, respirable*	0.5	0.05
silica-crystalline: tripoli*	0.5	0.05
silicate of soda, particulate	50	5
silicon carbide	40	4
silicon fluoride (as HF, 3hr)	4.9	0.5
silicon nitride	100	10
silicon tetrabromide	25	2.5
silicon tetrachloride	18	1.8
silicon tetrahydride	70	7
silicon tetraiodide	37	3.7
silicon, respirable	50	5
silicone, all	50	5
silver cyanide	0.1	0.01
silver metal	0.1	0.01
silver nitrate	0.1	0.01
silver, soluble compounds	0.1	0.01
soapstone, respirable	30	3
soda ash	50	5
sodium acifluorfen, particulate	50	5
sodium acrylamido-2-methypropane sulfonic acid	50	5
sodium alumina	20	2
sodium aluminate	20	2
sodium azide	2	0.2
sodium bisulfite	50	5
sodium borohydride	1	0.1
sodium chlorate	50	5
sodium dimethyldithiocarbamate	50	5
sodium dodecyl benzene sulfonate, particulate	100	10
sodium dodecyl benzene sulfonate, vapor	1000	100
sodium fluoroacetate	0.5	0.05
sodium hydrogen carbonate	20	2

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
sodium hydrosulfide	140	14
sodium hydroxide	20	2
sodium hypochlorite	15	1.5
sodium metabisulfite	50	5
sodium metasilicate	50	5
sodium methylate	20	2
sodium oxide, particulate	20	2
sodium perfluroacetate	0.5	0.05
sodium persulfate, particulate	10	1
sodium pyrithione	10	1
sodium pyrophosphate	50	5
sodium sulfate	50	5
sodium thiosulfate	50	5
sodium xylenesulfonate	20	2
sodium, 2,4-dichlorophenoxyethyl sulfate, respirable	50	5
Sol 100	1230	123
Solvesso 100	250	25
Solvesso 150	1000	100
soybean oil epoxide	100	10
starch, respirable	50	5
stearates	100	10
stearyl mercaptan	60	6
Steptozotocin	69	6.9
stibine**	5	0.5
stilbene	50	5
Stoddard solvent	3500	350
strontium and compounds	20	2
strontium chromate, as Cr	0.1	0.01
strychnine	1.5	0.15
styrene oxide	309	---
styrene, monomer (odor)	110	11
Subtilisins	0.0006	0.00006
succinic anhydride	25	2.5
succinonitrile	200	20
sucrose, respirable	50	5
Sulfinol	230	23
sulfolane	20	2
sulfolane raffinate	3500	350
sulfometuron methyl	50	5
sulfonates, alkyl	5	0.5
sulfonates, inorganic	20	2
Sulfonic N-95	600	60

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
Sulfotep	2	0.2
sulfur	50	5
sulfur chloride (odor)	5.6	0.56
sulfur dioxide**	TNRCC Reg II	
sulfur hexafluoride	600	60
sulfur monochloride (odor)	5.6	0.56
sulfur pentafluoride** (also evaluate HF)	0.5	0.05
sulfur tetrafluoride** (also evaluate HF)	2.2	0.22
sulfur trioxide**	10	1
sulfuric acid	TNRCC Reg II	
sulfurized isobutylenes	1750	175
sulfuryl chloride	36	3.6
sulfuryl fluoride	210	21
Sulprofos	10	1
Surfonamine	180	18
Systox	1	0.1
2,4,5-T	100	10
2,4,5-TP	100	10
Tackle, particulate	50	5
talc (no asbestos)	20	2
talc (with asbestos)	0.03	0.003
tall oil	100	10
tallow	100	10
tallow diamine	100	10
tantalum oxide	50	5
tantalum, metal	50	5
TEDP	2	0.2
tellurium and cmpds	1	0.1
tellurium hexafluoride** (as Te)	2	0.2
Temephos	50	5
Tenneco T500-100	2700	270
TEPP	0.47	0.047
terephthalic acid	100	10
Tergitol TP-9	600	60
terpenes	2000	200
terpenol	1000	100
terphenyls	50	5
tert-amyl methyl ether (odor)	520	52
tetrabromoethane, 1,1,2,2-	140	14
tetrachloro-1,2-difluoroethane,1,1,1,2-	16900	1690
tetrachloro-2,2-difluoroethane,1,1,1,2-	41700	4170
tetrachlorobenzenes (odor)	1000	100
tetrachlorodibenzo-p-dioxin,2,3,7,8-*	---	3 x 10-8
tetrachloroethane, 1,1,2,2-	70	7
tetrachloroethylene	340	34
tetrachloromethane	126	13
tetrachloronaphthalene	20	2
tetrachlorophenol, 2,3,4,6-(odor)	20	2
tetraethyl ammonium bromide	10	1
tetraethyl lead	0.75	0.075
tetraethylene glycol	100	10
tetraethylene glycol diacrylate	10	1
tetraethylene pentamine	400	40
tetraethylorthosilicate	850	85
tetraethylpyrophosphate	0.47	0.047
tetrafluoromethane	18000	1800
tetrafluroethane, 1,1,1,2-	20860	2086
tetrahydroammonium hydroxide	20	2
tetrahydrofuran	5900	590
tetrahydronaphthalene	3030	303
tetramethyl decyndiol	2200	220
tetramethyl lead**	0.75	0.075
tetramethyl succinonitrile	28	2.8
tetramethylammonium hydroxide	10	1
tetramethylene diamine	180	18
tetranitromethane**	0.4	0.04
tetrapropenylsuccinic anhydride	40	4
tetrasodium pyrophosphate	50	5
terpineol	1000	100
Tetryl	15	1.5
Texacat ZF-10	210	21
Texacat ZF-20	3.3	0.33
Texanol	835	84
thallic oxide	1	0.1
thallium & compounds	1	0.1
thiobis(6-t-butyl-m-cresol), 4,4'-	50	5
Thiofanox	8	0.8

Substance	Short-term ESL (µg/m^3)	Long-term ESL (µg/m^3)
thioglycolic acid (odor)	1.25	0.125
thionyl chloride	50	5
thiourea	50	5
Thiram	10	1
tin compounds: metal, oxide, and inorganic cpds	20	2
tin compounds: organic compounds	1	0.1
titanium dioxide, respirable	50	5
titanium tetrachloride**	10	1
tolidine, o-	0.2	0.02
toluene	1880	188
toluene sulfonyl chloride	50	5
toluene-2,4-diamine	50	5
toluene-2,4-diisocyanate	0.36	0.036
toluene-2,6-diisocyanate	0.36	0.036
toluenesulfonic acid, all isomers	20	2
toluidine, m-	88	8.8
toluidine, o-	88	8.8
toluidine, p-	88	8.8
tolyl glycidyl ether	30	3
tolylsulfonyl hydrazine	30	3
Toxaphene	5	0.5
tri(isobutenyl)succinic anhydride	10	1
triacetone amine	230	23
triadimenol	30	3
Triagen (>90% propyl bromide)	8000	800
triallylamine	60	6
triaminotrinitrobenzene	20	2
triazole-3-thiol, 1H-1,2,4-	63	6.3
tributyl phosphate	22	2.2
tributyl phosphine	4	0.4
tributyl phosphite	20	2
tributyltin oxide	0.5	0.05
trichloro-1,2,2-trifluoroethane, 1,1,2-	38000	3800
trichloroacetic acid	70	7
trichloroacetyl chloride	9	0.9
trichlorobenzene, 1,2,4-	400	40
trichloroethane, 1,1,1-	10800	1080
trichloroethane, 1,1,2-	550	55
trichloroethylene	1350	135

Substance	Short-term ESL (µg/m^3)	Long-term ESL (µg/m^3)
trichlorofluoromethane (odor)	28000	2800
trichloromethane**	98	9.8
trichloronaphthalene	50	5
trichloronitromethane	6.7	0.67
trichlorophenol, 2,4,5-	440	44
trichlorophenol, 2,4,6 (odor)	21	2.1
trichloropropane, 1,2,3-	600	60
trichloropropene, 1,2,3-	80	8
trichlorotrifluoroethane	38000	3800
triclopyr	40	4
tricresyl phosphate	5	0.5
tricyclohexyltin hydroxide	50	5
tridecyl alcohol	2700	270
tridymite*	0.5	0.05
triethanolamine	50	5
triethyl acetyl citrate	100	10
triethyl phosphate	500	50
triethyl phosphite	200	20
triethylamine	40	4
triethylene diamine	370	37
triethylene glycol	100	10
triethylene glycol diacrylate	10	1
triethylene glycol monobutyl ether	1000	100
triethylene glycol monoethyl ether	160	16
triethylene tetramine	240	24
trifluoroacetoaceytl chloride	20	2
trifluorobromomethane	61000	6100
trifluoroethane, 1,1,1-	17140	1714
trifluoromethane	14300	1430
Trifluralin	100	10
triglycidyl-s-triazinetrione	0.5	0.05
triisopropyl phosphine	4	0.4
trimetacresyl phosphate	3	0.3
trimethoxybenzoate, 3,4,5-	7	0.7
trimethyl acetic acid	250	25
trimethyl benzene	1250	125
trimethyl benzene, 1,3,5-	1250	125
trimethyl bicyclohep-3-ene, 3,7,7-	220	22
trimethyl borate	13	1.3
trimethyl phosphite (odor)	0.5	0.05

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
trimethyl trioxane	440	44
trimethyl-1,3-pentanediol isobutyrate, 2,2,4-	835	84
trimethyl-4-nonanone, 2,6,8-	3750	375
trimethylamine (odor)	1	0.1
trimethylammoniumacrylate chloride	135	14
trimethylene diamine	50	5
trimethylol propane	50	5
trimethylol propane ethoxytriacrylate	10	1
trimethylol propane triacrylate	10	1
trimethylol propane trimethyl acrylate	10	1
trimethylpentane, 1,2,4-	3500	350
trinitrophenol (odor)	0.5	0.05
trinitrophenyl methylnitramine	15	1.5
trinitrotoluene	1	0.1
triorthocresyl phosphate	1	0.1
trioxane	190	19
triparacresyl phosphate	3	0.3
triphenyl phosphate	30	3
triphenyl phosphine	4	0.4
triphenyl phosphite	25	2.5
triphenylamine	50	5
tripoli*	0.5	0.05
tripropylamine	16	1.6
tripropylene glycol, particulate	25	2.5
tripropylene glycol, vapor	400	40
tris(1-aziridinyl) phosphine sulfide	0.6	0.06
tris(2-chloroethyl) phosphate	430	43
tris(chloropropyl) phosphate	1250	125
tris(dimethylaminomethyl)phenol	420	42
tris(hydroxyphenyl) ethane	60	6
tris(nonylphenol)phosphite	30	3
trisodium phosphate	50	5
Trithion	1	0.1
tritolyl phosphate	5	0.5
Triton X-100 Surfactant	1000	100
tungsten hexafluoride (as HF, 3hr)	4.9	0.5

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
tungsten, insoluble compounds	50	5
tungsten, soluble compounds	10	1
turpentine	5560	556
Unamine T	50	5
undecanoic acid (odor)	11	1.1
undecyl mercaptan	39	3.9
uracil mustard	0.8	0.08
uranium, insoluble compounds	2	0.2
uranium, soluble compounds	0.5	0.05
urea	100	10
urethane	5	0.5
V,M&P naphtha	3500	35
valeraldehyde (odor)	98	9.8
valeric acid (odor)	3	0.3
vanadium pentoxide	0.5	0.05
vanillin	100	10
Varsol	3500	350
vegetable oil mists, respirable	50	5
Velpar	50	5
Veratrole	24	2.4
Versamine	250	25
vinyl 2,2-dimethyl propanoate	55	5.5
vinyl acetate**	150	15
vinyl acetate polymer, particulate	100	10
vinyl benzene (odor)	110	11
vinyl bromide	220	22
vinyl chloride	130	13
vinyl cyanide**	43	4.3
vinyl cyclohexene dioxide*	5.7	0.57
vinyl cyclohexene, 4-	4	0.4
vinyl fluoride (water insoluble)	19	2
vinyl methyl ether	9700	970
vinyl methyl ketone	6	0.6
vinyl pivalate	55	5.5
vinyl toluene	2420	242
vinyl-2-ethylhexoate	200	20
vinyl-2-norbornene, 5-	425	42.5
vinyl-2-pyrrolidone, 1-	180	18
vinylidene chloride	40	4

Substance	Short-term ESL ($\mu g/m^3$)	Long-term ESL ($\mu g/m^3$)
vinylidene fluoride	26	2.6
Warfarin	1	0.1
water conditioners	10	1
welding fumes	50	5
wollastonite	50	5
wood dust, hardwoods	10	1
wood dust, soft woods	50	5
wood dust, Western red cedar	10	1
xylene, mixed or all isomers, except p- (odor)	3700	370
xylene, p- (odor)	2079	208
xylene-a,a'-diamine, m-	1	0.1
xylenol, all isomers	165	16.5
xylidine, mixed isomers	25	2.5
yttrium	10	1
zinc beryllium silicate, particulate (as Be)	0.02	0.002
zinc bromide	10	1
zinc chloride fume	10	1
zinc chromates (as Cr)	0.1	0.01
zinc oxide dust	50	5
zinc oxide fume	50	5
zinc stearate, respirable	50	5
zirconium compounds (as Zr)	50	5
zoalene	50	5
Zorial	100	10

* currently under review

** constituent has disaster potential

Table A7-5 WHO guidelines for air quality: compounds with non-carcinogenic health endpoints

Compound	Average ambient air concentration [$\mu g/m^3$]	Health endpoint	Observed effect level [mg/m^3]	Uncertainty factor	Guideline Value (GV) or Tolerable Concentration (TC) [$\mu g/m^3$]	Averaging time	Source	
Acetaldehyde	5	Irritancy in humans	45 (NOAEL)	20	2 000 (TC)	24 hours	WHO 1995d	EHC 167
		Carcinogenicity related irritation in rats	275 (NOAEL)	1000	50 (TC)	1 year		
Acetone	0.5-125	Odour annoyance	240 (OT)	n.a.	n.p.	-	WHO 1998c	EHC 207
Acrolein	15	Eye irritation in humans	0.13	n.p.	50 (GV)	30 min	WHO 1992b	EHC 127
		Odour annoyance	0.07	n.a.	-	30 min	WHO 1992b	EHC 127
Acrylic acid	No data	Nasal lesions in mice	15 (LOAEL)	50	54 (GV)	1 year	WHO 1997d	EHC 191
2-Butoxyethanol	0.1-15	Haematoxicity in rats	242 (NOAEL)	10	13100 (TC)	1 week	WHO 1998d	CICAD 10
1,4 Dichlorobenzene	0.2-3.5	Increase in organ weight and urinary proteins	450 (NOAEL)	500	1000 (TC)	1 year	WHO 1991a	EHC 128
Dichloromethane	< 5	COHb formation in normal subjects		n.a.	3000 (GV)	24 hours	WHO 1999a	
Diesel exhaust	1.0 - 10.0	Chronic alveolar inflammation in humans	0.139 (NOAEL)*	25	5.6 (GV)	1 year	WHO 1996b	EHC 171
		Chronic alveolar inflammation in rats	0.23 (NOAEL)*	100	2.3 (GV)	1 year		
2-Ethoxyethanol	No data	Developmental effects in rats	37 (NOAEL)	n.p.	n.p.	1 year	WHO 1990a	EHC 115
2-Ethoxyethylacetate	No data	Developmental effects in rats	170 (NOAEL)	n.p.	n.p.		WHO 1990a	EHC 115
Ethylbenzene	1-100	Increase of organ weight	2150 (NOAEL)	100	22 000 (GV)	1 year	WHO 1996c	EHC 186
Formaldehyde	(1-20) x 10^{-3}	Nose, throat irritation in humans	0.1 (NOAEL)	n.a.	100 (GV)	30 min	WHO 1999a	

Compound	Average ambient air concentration [μg/m^3]	Health endpoint	Observed effect level [mg/m^3]	Uncertainty factor	Guideline Value (GV) or Tolerable Concentration (TC) [μg/m^3]	Averaging time	Source	
Hexachlorocyclopentadiene	No data	Inhalation effects in rats	0.45 (NOAEL)	n.p.	n.p.	1 year	WHO 1991b	EHC 120
Isophorone	No data	Odour annoyance	1.14 (OT)	n.a.	-	30 min	WHO 1995f	EHC 174
2-Methoxyethanol	No data	Developmental toxicity in rats	31 (NOAEL)	n.p.	n.p.		WHO 1990a	EHC 115
Methyl bromide	0.05-0.8	Reduction in fertility index in rats	12 (NOAEL)	n.p.	n.p.		WHO 1995g	EHC 166
Methyl Methacrylate	2.4 x 10^{-4}	Degenerate changes in olfactory epithelium in rodents	102.5 (NOAEL)	100	200 (TC)	1 year	WHO 1998e	CICAD 4
Monochlorobenzene	0.2-3.5	Decreased food intake, increased organ weight, lesions and changes in blood parameters	341 (LOAEL)	1000	500 (TC)	1 year	WHO 1991a	EHC 128
1-Propanol	0.05	Reproduction in pregnant rats	9001 (NOAEL)	n.p.	n.p.		WHO 1990b	EHC 102
2-Propanol	1500-35000	Developmental toxicity in rats	9001 (LOEL)	n.p.	n.p.		WHO 1990c	EHC 103
Styrene	1.0 -20.0	Neurological effects in workers	107 (LOAEL)	40	260 (GV)	1 week	WHO 1999a	
		Odour annoyance	0.07 (OT)	n.a.	7 (GV)	30 minutes	WHO 1987	
Tetrachloroethylene	1 - 5	Kidney effects in workers	102 (LOAEL)	400	250 (GV)	24 hours	WHO 1999a	
		Odour annoyance	8	n.a.	8000 (GV)	30 minutes	WHO 1987	
1,1,1,2-Tetrafluoroethane	No data	Development toxicity in animals	41700 (NOAEL)	n.p.	n.p.		WHO 1998f	CICAD 11
Toluene	5 - 150	Effects on CNS in workers	332 (LOAEL)	1260	260 (GV)	1 week	WHO 1999a	
		Odour annoyance	1 (OT)	n.a.	1000 (GV)	30 minutes	WHO 1987	

Compound	Average ambient air concentration [μg/m³]	Health endpoint	Observed effect level [mg/m³]	Uncertainty factor	Guideline Value (GV) or Tolerable Concentration (TC) [μg/m³]	Averaging time	Source	
1,3,5 Trichlorobenzene	0.5-0.8	Metaplasia and hyzperplasia of respiratory epithelium in rats	100 (NOAEL)	500	200 (TC)	1 year	WHO 1991a	EHC 128
1,2,4 Trichlorobenzene	0.02-0.05	Increae in urinary porphyrins in rats	22.3 (NOAEL)	500	50 (TC)	1 year	WHO 1991a	EHC 128
Xylenes	1 - 100	CNS effects in human volunteers	304 (NOAEL)	60	4800 (GV)	24 hours	WHO 1997g	EHC 190
		Neurotoxicity in rats	870 (LOAEL)	1000	870 (GV)	1 year		
		Odour annoyance	4.35 (OT)	n.a.	-	30 minutes		

n.a.: not applicable
n.p.: not provided
OT: Odour Threshold

Table A7-6 WHO guidelines for air pollutants with carcinogenic health endpoints

Compound	Average ambient air concentration [mg/m^3]	Health endpoint	Unit risk [mg/m^3]$^{-1}$	IARC classification	Source	
Acetaldehyde	5	Nasal tumours in rats	(1.5-9) x 10^{-7}	2B	WHO 1995d	EHC 167
Acrylonitrile	0.01 - 10	Lung cancer in workers	2 x 10^{-5}	2A	WHO 1987	
Benzene	5.0 - 20.0	Leukemia in exposed workers	(4.4-7.5) x 10^{-6}	1	WHO 1999a	
Benzo[a]pyrene		Lung cancer in humans	8.7 x 10^{-2}	1	WHO 1999a	
Bis(chloromethyl)ether	No data	Epitheliomas in rats	8.3 x 10^{-3}	1	WHO 1998h	EHC 201
Chloroform	0.3-10	Kidney tumours in rats	4.2 x 10^{-7}	2B	WHO 1994b	EHC 163
1,2-Dichloroethane	0.07 x 10^{-4}	Tumour formation in rodents	(0.5-2.8) x 10^{-6}	2B	WHO 1998g	CICAD 1
Diesel exhaust	1.0 - 10.0	Lung cancer in rats	(1.6-7.1) x 10^{-5}	2A	WHO 1996b	EHC 171
ETS	1-10	Lung cancer in exposed humans	1 x 10^{-3}		WHO 1999a	
PAH (BaP)	(1-10) x 10^{-3}	Lung cancer in exposed humans	8.7 x 10^{-2}	1	WHO 1999a	
1,1,2,2-Tetrachloroethane	0.1 - 0.7	Hepatocellular carcinomas in mice	(0.6-3.0) x 10^{-6}	3	WHO 1998j	CICAD 3
Trichloroethylene	1-10	Cell tumours in testes of rats	4.3 x 10^{-7}	2A	WHO 1999a	
Vinyl chloride	0.1 – 10	Hemangiosarkoma in exposed workers; liver cancer in exposed workers	1 x 10^{-6}	1	WHO 1987	